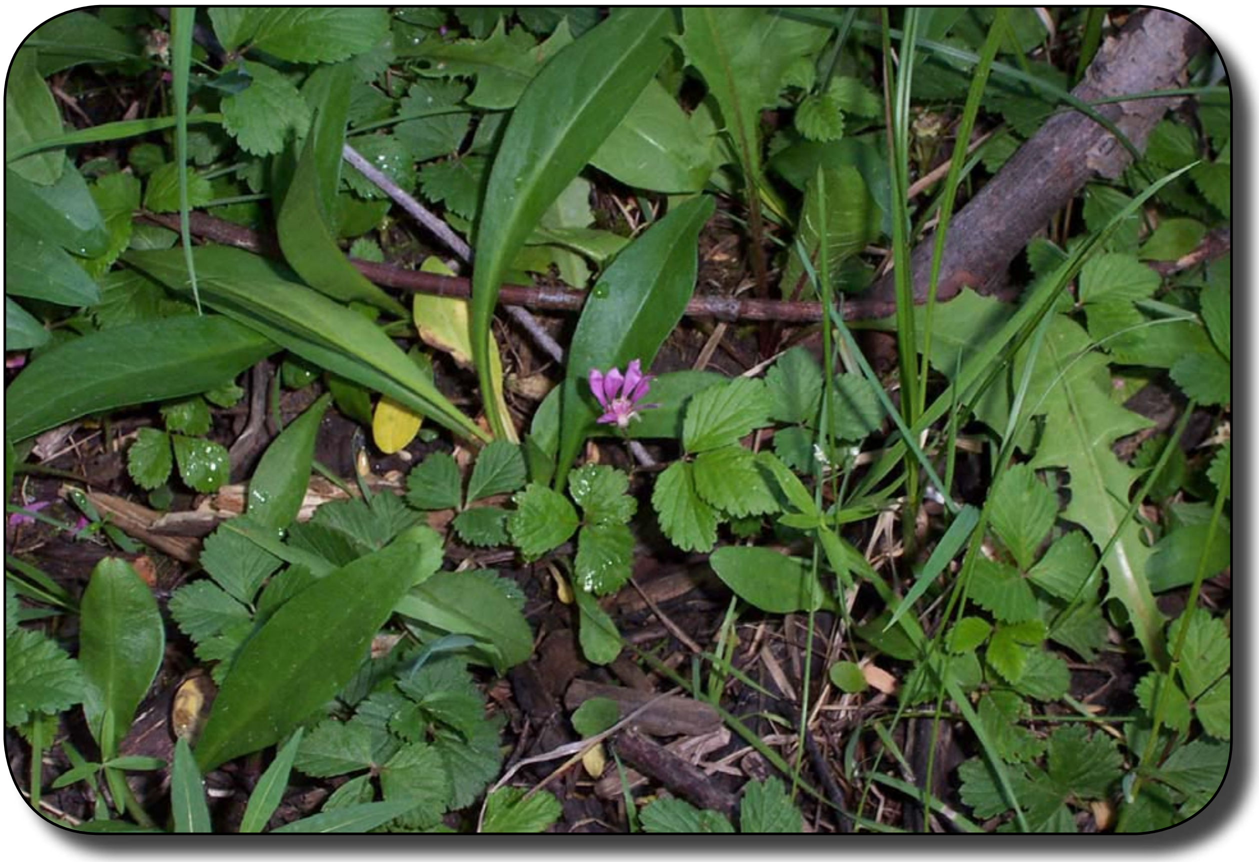
Rubus arcticus L. ssp. *acaulis* (Michaux) Focke (dwarf raspberry): A Technical Conservation Assessment



Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

October 18, 2006

Juanita A. R. Ladyman, Ph.D.
JnJ Associates LLC
6760 S. Kit Carson Cir E.
Centennial, CO 80122

Peer Review Administered by
Society for Conservation Biology

Ladyman, J.A.R. (2006, October 18). *Rubus arcticus* L. ssp. *acaulis* (Michaux) Focke (dwarf raspberry): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/rubusarcticussspacaulis.pdf [date of access].

ACKNOWLEDGMENTS

The time spent and help given by all the people and institutions mentioned in the reference section are gratefully acknowledged. I would also like to thank the Wyoming Natural Diversity Database, in particular Bonnie Heidel, and the Colorado Natural Heritage Program, in particular David Anderson, for their generosity in making their records available. The data provided by Lynn Black of the DAO Herbarium and National Vascular Plant Identification Service in Ontario, Marta Donovan and Jenifer Penny of the British Columbia Conservation Data Center, Jane Bowles of University of Western Ontario Herbarium, Dr. Kadri Karp of the Aianduse Instituut in Tartu, Greg Karow of the Bighorn National Forest, Cathy Seibert of the University of Montana Herbarium, Dr. Anita Cholewa of the University of Minnesota Herbarium, Dr. Debra Trock of the Michigan State University Herbarium, John Rintoul of the Alberta Natural Heritage Information Centre, and Prof. Ron Hartman and Joy Handley of the Rocky Mountain Herbarium at Laramie, were all very valuable in producing this assessment. I also appreciate Andrew Kratz, USDA Forest Service Region 2, and Chuck Davis, U.S. Fish and Wildlife Service, both in Denver, Colorado, for giving me access to their files. The time spent by Steve Olson of Pike-San Isabel National Forest and Comanche and Cimarron national grasslands in searching for *Rubus arcticus* ssp. *acaulis* is also appreciated. I would also like to thank Deb Golanty at the Helen Fowler Library, Denver Botanic Gardens, for her persistence in retrieving some rather obscure articles. I also acknowledge the help provided by D.L. Gustafson and Martin Wefald, Montana State University, for making the Graphical Locator available on the Internet. I appreciate the thoughtful reviews of Kathy Carsey, Kathy Roche, Dr. David Inouye and Dr. Carol Kearns and thank them for their time and consideration of the assessment.

AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 15 years, she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates*, an environmental consulting company in Colorado.

COVER PHOTO CREDIT

Rubus arcticus ssp. *acaulis*. Photograph by John Proctor, USDA Forest Service.

Summary of Key Components for Conservation of *Rubus arcticus* ssp. *acaulis*

Status

Rubus arcticus ssp. *acaulis* (dwarf raspberry) is a small herbaceous plant in the rose family that is restricted to North America and possibly Siberia. Although a relatively widespread species, occurrences of *R. arcticus* ssp. *acaulis* are few and tend to be widely separated and particularly disjunct within the continental United States. In USDA Forest Service (USFS) Region 2, this taxon is known from mountainous areas in Colorado and Wyoming. Eight of the ten documented occurrences in Colorado and Wyoming are on National Forest System lands.

Rubus arcticus ssp. *acaulis* is designated a sensitive species by the USFS Region 2, Region 9, and parts of Region 6. The NatureServe Global rank for *R. arcticus* ssp. *acaulis* is G5T5, demonstrably widespread, abundant, and secure. In Region 2, both the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database designate it critically imperiled (S1). These state and global ranks have no regulatory status. *Rubus arcticus* ssp. *acaulis* is not listed as threatened or endangered under the Endangered Species Act, nor is it a candidate for listing (ESA of 1973, U.S. C. 1531-1536, 1538-1540).

Primary Threats

The most likely immediate and potential threat to *Rubus arcticus* ssp. *acaulis* occurrences is habitat loss. Anthropogenic causes of habitat loss include human recreation activities, livestock grazing, and extraction of natural resources (e.g., timber and peat). Logging, recreation, and water impoundments have been reported as the main threats to *R. arcticus* ssp. *acaulis* populations in Wyoming. Road construction and improvements may pose a threat to some occurrences, particularly those in Region 2. Water availability may be one of the most critical environmental variables for *R. arcticus* ssp. *acaulis*, and any circumstance that leads to drier habitat conditions is likely to pose a substantial threat. As the human population grows in areas within easy access to *R. arcticus* ssp. *acaulis* habitat and as recreational use increases, the impacts may become substantially more significant. This is particularly true for Colorado where the human population increased 30.6 percent between 1990 and 2000. Invasive, non-native plant species may threaten some occurrences by directly competing with *R. arcticus* ssp. *acaulis* for resources and by contributing to habitat degradation. Wildlife browsing and trampling may pose a threat, especially when combined with livestock grazing pressure. The consequences of fire and fire suppression are unknown, but they may affect the availability of suitable habitat. Recreational and commercial berry picking appears to be a substantial threat to *R. arcticus* ssp. *acaulis* occurrences that are within easy reach of urban centers in northern regions, but collection of *R. arcticus* ssp. *acaulis* fruit is not considered a threat in Region 2. Like all species, *R. arcticus* ssp. *acaulis* occurrences are vulnerable to environmental stochasticity and natural catastrophes. Warmer temperatures and/or drier conditions associated with global climate change are potential threats. Atmospheric nitrogen deposition may also threaten some occurrences, such as those in the Front Range in Colorado. The role of cross-pollination in *R. arcticus* ssp. *acaulis* population maintenance is not documented, but the species may be vulnerable over the long term to declines in pollinator populations. Demographic and genetic stochasticities are also potential threats, and it is likely that small and disjunct *R. arcticus* ssp. *acaulis* occurrences, such as those in Wyoming and Colorado, are the most vulnerable.

Primary Conservation Elements, Management Implications and Considerations

Rubus arcticus ssp. *acaulis* is restricted to North America. It is relatively common and widespread in some regions of Canada and Alaska but infrequent within the continental United States. However, there is a lack of detailed information concerning the abundance, distribution, and biology of *R. arcticus* ssp. *acaulis* throughout its range. In Colorado and Wyoming, the majority of the known occurrences are on land managed by the USFS Region 2. *Rubus arcticus* ssp. *acaulis* typically requires mesic to wet conditions and is likely to be sensitive to hydrological changes in its environment. Relatively long-lived mature individuals are apparently important to the persistence of *R. arcticus* ssp. *acaulis* populations, and thus management practices that increase either the frequency or intensity of natural perturbations, or by themselves apply additional stresses to the plants, may significantly and negatively impact population viability. Conversely, periodic fire may maintain habitat, and long-term fire suppression policies may have contributed to loss of habitat. There are no existing management plans directly concerning *R. arcticus* ssp. *acaulis*. The population on the Bighorn National Forest, Region 2, has been monitored at yearly internals since 1999. The current distribution data suggest that this taxon may be found in any bog or fen area above 7,000 ft. within Region 2. Maintaining wet habitats, monitoring known populations within Region 2, and finding new occurrences are important management priorities for this taxon.

TABLE OF CONTENTS

EDITORS: Kathy Roche and Kathy Carsey, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Tables:

Figures:

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Rubus arcticus* ssp. *acaulis* (dwarf raspberry) is the focus of an assessment because it has sensitive species status in Region 2. Within the National Forest System, a sensitive species is a plant or animal "for which population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce a species distribution" (Forest Service Manual 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *R. arcticus* ssp. *acaulis* throughout its range in Region 2. The introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and an outline of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope

This assessment examines the biology, ecology, conservation, and management of *Rubus arcticus* ssp. *acaulis* with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the literature relevant to the species may originate from field investigations outside the region, this document places that literature in the ecological and social contexts of the central and southern Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *R. arcticus* ssp. *acaulis* in the context of the current environment rather than under historical conditions. The evolutionary and historical environment of the species is considered in conducting this synthesis, but placed in a current context.

In producing the assessment, refereed (peer-reviewed) literature, non-refereed (not peer-reviewed) publications, research reports, and data accumulated by resource management agencies were reviewed. Although an effort was made to consider all relevant documents, some publications on *Rubus arcticus* ssp. *acaulis* may not have been referenced in this assessment. The assessment emphasizes refereed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment because information was unavailable elsewhere. In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many reports or non-refereed publications on rare plants are reliable and non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established (e.g., Fertig 2000b). Insufficient funding or manpower may have prevented work in subsequent years. Although one year of data is generally considered inadequate for publication in a refereed journal, it still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (e.g., Natural Heritage Program and herbarium records) were important in estimating the geographic distribution and population sizes of this species. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted more heavily than observations alone.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference as described by Platt, suggests that experiments will produce clean results (Hillborn and

Mangel 1997), as may be observed in certain physical sciences. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are evaluated based on observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, logical thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

In this assessment, the strength of evidence for articulate ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted approaches to understanding.

Uncertainty has persisted as to whether *Rubus acaulis* is a unique species, a subspecies of *R. arcticus*, or whether it should be recognized only as one of the polymorphic forms of *R. arcticus* (Porsild 1951, Hultén 1968, Welsh 1974, USDA Forest Service 2002). Additional uncertainty is generated by a possibility of mistaken identity. In its vegetative form, *R. arcticus* ssp. *acaulis* can be mistaken for *R. pubescens* and even species of *Fragaria* (strawberry). Mistaken identity can lead to over- and underestimates of abundance. This situation indicates that specimen collection and deposition at accessible herbaria are very important considerations for this taxon. Evidence of hybridization between species has also added to the uncertainty in abundance and range. Even in the absence of hybridization and similarity to other taxa, the rarity of a taxon can be difficult to establish. There is the always the possibility that additional surveys would reveal more occurrences. Perceived rarity can be relative, and many taxa are regarded as not being rare precisely because casual observation has noted that they occur frequently.

When reading this report, it is important to remember that the physiology and reproductive biology of *Rubus arcticus* ssp. *arcticus* and *R. arcticus* ssp. *acaulis* may differ considerably. Because the berries of *R. arcticus* ssp. *arcticus* have such commercial importance, much research has been conducted on that taxon whereas information on *R. arcticus* ssp. *acaulis* is lacking. In this report, where information on subspecies *acaulis* is unavailable, information as it applies to subspecies *arcticus* is reported. In all cases, the subspecies is named, and the reader needs to consider that differences might exist between the two subspecies.

Publication of the Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication will facilitate the revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Society of Conservation Biology employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

Management Status and Natural History

Management Status

Rubus arcticus ssp. *acaulis* is designated a sensitive species in Region 2 (USDA Forest Service 2005). Sensitive species designation refers to a species identified by the Regional Forester "for which population viability is a concern as evidenced by a significant current or predicted downward trend in population number or density and/or a significant current or predicted downward trend in habitat capability that would reduce a species' existing distribution" (USDA Forest Service 1994).

Rubus arcticus ssp. *acaulis*, as *R. acaulis*, is designated sensitive by the USFS Region 6, Washington State, where it is documented from the Okanogan National Forest (Holmes personal communication 2004, USDA Forest Service 2005). The taxon is also listed as sensitive in Region 9 (USDA Forest Service 2005), where it is known from the Hiawatha National Forest in Michigan (USDA Forest Service 2002).

NatureServe and many state natural resource inventory programs rank taxa at state (S) and global (G) levels on a scale of 1 to 5. A ranking of 1 indicates the most vulnerable and 5 the most secure (see Ranks in the **Definitions** section). These ranks carry no regulatory status. The NatureServe Global[1] rank for *Rubus arcticus* ssp. *acaulis* is G5T5, demonstrably widespread, abundant, and secure (NatureServe 2004). Within Region 2, the Colorado Natural Heritage Program (2003) and the Wyoming Natural Diversity Database (2005) rank the taxon as critically imperiled (S1).

Outside of Region 2, the status of the taxon varies considerably. The Michigan Natural Features Inventory (2005) and the Washington Natural Heritage Program (2004) rank *Rubus arcticus* ssp. *acaulis* as critically imperiled (S1). *Rubus arcticus*, without qualification at the subspecies level, is currently considered as "possibly at risk, SU," in Montana, but more information is needed to rank it in that state (Montana Natural Heritage Program 2005). *Rubus arcticus* ssp. *acaulis* was considered for sensitive status by USFS Region 1 in the state of Montana but was rejected; the reason for the rejection was not given (Lesica and Shelly 1991). Although not formally ranked in Alaska (NatureServe 2004), it is treated as a rank S4S5, apparently secure or possibly widespread and abundant (Lipkin personal communication 2003). *Rubus arcticus* ssp. *acaulis* is not considered sensitive in Maine (Maine Natural Areas Program 2004), Minnesota (NatureServe 2004), or Oregon (Oregon Natural Heritage Information Center 2004) and remains reported but unranked (SNR) in those states (NatureServe 2004). Occurrences of *R. arcticus* ssp. *acaulis* in Oregon and Maine need confirmation because well-documented reports or herbarium specimens from these states cannot be located for this report.

In Canada, *Rubus arcticus* ssp. *acaulis* is generally more abundant than in Region 2, with ranks between S2 and S5. It is designated between imperiled and vulnerable (S2S3) on Newfoundland Island (NatureServe 2004). In British Columbia, it is ranked apparently secure (S4) and is estimated to be between vulnerable and secure (S3S5) in Labrador. *Rubus arcticus* ssp. *acaulis* is considered widespread and abundant (S5) in Saskatchewan. The Alberta Conservation Data Center does not recognize subspecies of *R. arcticus*, which is ranked S5, abundant (Rintoul personal communication 2004). The taxon remains reported but unranked (SNR) for Manitoba, Northwest Territories, Nunavut, Ontario, Quebec, and Yukon Territory (NatureServe 2004).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Within Colorado and Wyoming, most occurrences of *Rubus arcticus* ssp. *acaulis* are on lands managed by the USFS Region 2 although the taxon is also known from National Park Service lands and may occur on private lands (**Table 1**). National forests originally were managed for timber harvesting and maintaining good water quality (USDA Forest Service 1933). Since that time, management goals have been expanded, and for the years 2004 through 2008, goals include:

- increasing the health of national forests and grasslands so that they will be resilient to the effects of invasive species and wildfire
- providing high-quality outdoor recreational opportunities on national forests and grasslands while sustaining natural resources
- contributing to meeting the Nation's need for energy
- improving watershed conditions (USDA Forest Service 2004a).

National parks are managed for their scenic or historical significance and emphasize human recreation and education more than national forests or wilderness areas. Logging, mining, and many other extractive activities are usually prohibited (National Park Service Undated, National Park Service Organic Act 1916, Environmental Media Services 2001). In their management plans, national parks typically consider species that state resources conservation programs designate as sensitive or rare. *Rubus arcticus* ssp. *acaulis* is currently protected from development projects in Yellowstone National Park (Whipple personal communication 2006).

Numerous USFS codes and regulations provide direction for activities on National Forest System lands: the Organic Administration Act of 1897 (16 U.S. C. 475), the Multiple Use – Sustained Yield Act of 1960 (16 U. S. C. 528), the National Forest Management Act of 1976 (16 U.S.C.1600-1602, 1604,1606, 1608-1614), the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701-1782, FSM 2729), the Forest Service Manual, and individual Forest Management Plans. The National Environmental Policy Act (NEPA) requires

[1] For definitions of G and S ranking see Ranks in the **Definitions** section at the end of this document.

Table 1. Summary of the available information for each *Rubus arcticus* ssp. *acaulis* occurrence site in Colorado and Wyoming, including occurrences in Region 2. Those occurrences with specimen verification are indicated in the column marked "Source."

Arbitrary occurrence no.	State	County	Observation dates	Management	Location	Habitat	Abundance and comments	Source[1]
1	Colorado	Park	26-Jun-1966	Pike National Forest	Geneva Park.	In meadow-bog in organic soil; slope is 0-5% with east exposure; associated species: *Salix* sp., *Potentilla fruticosa*, *Carex* sp., *Deschampsia caespitosa*, *Fragaria* sp.; elevation approximately 9,720 ft.	Locally abundant; dark rose flower color; perennial herb. "Range condition: non-range." Comment made that it has "low forage value".	*R.K. Gierisch and W.C. Hickey #3100* 1966 COLO and RM; Colorado Natural Heritage Program (2003)
2	Colorado	Park	25-Jul-1979, 1995, 12-Sep-2000, 26-Jun-2004	Pike National Forest	Geneva Park - just across the road from Abyss Trailhead of Guanella Pass.	1979: Common on peat hummocks in willow bog at outlet of meadow. 1995: Glaciated mountain valley. Fen/willow Carr-hummocks in fen. Moist to wet peat soils. Slope 0%, aspect flat in open light exposure and partial shade. Tree cover: 0%. Shrub cover: 40%. Forb cover: 10%. Graminoid cover: 20%. Associates: *Salix planifolia, S. brachycarpa, Primula incana, Carex parryana*, and *Pentaphylloides floribunda.* 2000: Hummocky fen habitat; plants were growing with *Salix planifolia, Pentaphylloides floribunda, Betula glandulosa, Carex aquatilis, Thalictrum alpinum*; growing in moss. Habitat in good condition; elevation approximately 9,600- 9,700 ft.	1979: Common. 1995: Estimated number of individuals: several thousand in 30 acres. Most vegetative, a few flowering. 2000: Common in small fen; difficult to estimate population size because plants post flowering.	*W.A. Weber #15481* 1979 COLO; Colorado Natural Heritage Program (2003)
3	Colorado	Grand	17-Jul-1935	Arapaho National Forest	1935: Campground on Willow Creek, south of Willow Pass.	Elevation approximately 8,800 ft.	Specimen in flower; flowers dried purple.	*A. Nelson and R. #2221* RM 1935 (Collection filled two sheets); Colorado Natural Heritage Program (2003)

Table 1 (cont.).

Arbitrary occurrence no.	State	County	Observation dates	Management	Location	Habitat	Abundance and comments	Source[1]
4	Colorado	Grand	16-Aug-1951, 29-Jun-1961, 14-Jul-1998, 15-Jul-2005	Arapaho National Forest	1951: Swampy flats bordering Willow Creek just above its junction with Denver Creek approximately 5 miles south of Willow Creek Pass. 1961: Denver Creek Campground, approximately 16 miles northwest of Granby. 2005: Willow Creek.	1951: Swampy flats bordering the creek. 1961: Along the bank of the Creek in deep moss cover. 1998: In moist riparian corridor; total tree cover 0-5%; total shrub cover 80-95%; total forb cover 70%; total graminoid cover 40-60%; total moss/lichen cover 40%; associated plant community: mature *Salix* spp., sparse *Pinus contorta, Carex aquatilis, Fragaria virginiana, Betula glandulosa*; in the floodplain at the bottom portion of concave-shaped slopes (1-10% incline) with west and east aspect in partial and full shade; the area is always moist and seasonally saturated; soils are sandy gravel with some cobbles; elevation 8,500-8,600 ft.	1951: Locally abundant but rarely fruiting. 1961: No information. 1998: Estimated. number of individuals: 150-200 aerial stems in 3 sub-populations over a 0.5-acre area; all vegetative, no fruits, "3 old flowers seen." 2005: "Hundreds approaching thousands of aerial stems but only a few flowers."	*W.A. Weber #7262* 1951 COLO, RM; *B.E. Willard #6162 with R.A. Nelson* 1961 COLO Proctor personal communication 2005; Colorado Natural Heritage Program (2003)
5	Colorado	Grand	23-Aug-1993	Arapaho National Forest	Near intersection between FS road 112 and Highway 125.	With *Pinus contorta, Salix lucida, S. monticola, S. geyeriana, Calamagrostis canadensis*; elevation approximately 8,460 ft.	No information.	Colorado Natural Heritage Program (2003)

Table 1 (cont.).

Arbitrary occurrence no.	State	County	Observation dates	Management	Location	Habitat	Abundance and comments	Source[1]
6	Wyoming	Johnson	10-Aug-1994, 19-Jul-1999	Bighorn National Forest	East slope Bighorn Range, along Sourdough Creek between 0.25 air miles northeast of US Highway 16 northeast to ca 0.2 air miles northeast of confluence of Sourdough and Little Sourdough Creeks, 11-12 air miles southwest of Buffalo .	Occurs in two main habitats: (1) Open to partially shaded mossy hummocks on banks and gentle slopes within *Salix planifolia thickets* and *Carex rostrata/C. aquatilis/ Calamagrostis canadensis* marshes. Soils moist (but usually not flooded) and organic rich histisols or inceptisols derived from granitic alluvium. May also occur sporadically on abandoned beaver lodges and dams. (2) Shady banks of A/B type creek in understory of *Picea engelmannii/ Linnaea borealis* community with medium to high moss cover or needle duff on sandy to granite-derived soils; these banks are flooded during spring runoff. 1994: Occurs with *Linnea borealis, Deschampsia caespitosa, Allium brevistylum,* and *Streptopus amplexifolius*. Elevation 7,440-7,740 ft. Jul-1995: Associated with *S. planifolia* var. *planifolia, Pedicularis groenlandica, Trifolium pratensis, Thalictrum venulosum, Carex aquatilis, Taraxacum officinale, Aconitum columbianum, Equisetum arvense*, and moss. Also occasionally with *Picea engelmannii* and *Potentilla fruticosa*. Jun-1995: Associated with *Picea engelmannii, S. planifolia* var. *planifolia*, *C. aquatilis, Pyrola minor, Epilobium angustifolium, Equisetum arvense*, and *Fragaria virginiana*.	Population consists of 10 subpopulations along a 1.5-mile stretch of Sourdough Creek; most colonies are on the south bank, except for the lowermost 0.5 miles; total occupied approximately 5 acres. 18 Jul 1995: Observed in flower; individuals estimated to be in the thousands along a 1.5-mile stretch of Creek. 21/22-Jun-1995: Several (approximately 6) small clumpy subpopulations with 2-60 individuals 10-Aug-1994: 2 vegetative plants observed; area is within a cattle allotment; northeastern most subpopulation is in Bighorn National Forest is in Ecodata plot #021E944015.	*S. Mills and K. Zacharkevics #s.n.* 1994 Bighorn National Herbarium (Photocopy at RM); *W. Fertig, #18781, 18790* 1999 RM; Wyoming Natural Diversity Database (2003)
7	Wyoming	Johnson	20-Jul-1900, 15-Aug-1900	Bighorn National Forest	East slope Bighorn Range, headwaters of Clear Creek and Crazy Woman River; [General collecting location over 1 month period]; this is near or represents the same population as occurrence 6.	Elevation 7,000-9,000 ft.	No information	*F. Tweedy #3244* 1900-07-20 RM; Wyoming Natural Diversity Database (2003)

Table 1 (concluded).

Arbitrary occurrence no.	State	County	Observation dates	Management	Location	Habitat	Abundance and comments	Source[1]
8	Wyoming	Teton	28-Jun-1995	Yellowstone National Park	Yellowstone Plateau, Witch Creek at south end of the Heart Lake Geyser Basin.	Moist spruce-fir copse; elevation approximately 7,460 ft.	No information.	*J. Whipple #s.n.* Yellowstone National Park Herbarium. Wyoming Natural Diversity Database (2003)
9	Wyoming	Teton	Pre-1980, 07-Jul-1997	Yellowstone National Park	Yellowstone Plateau, banks of small creek draining into northeast shore of Heart Lake approximately 0.4 miles northwest of the outlet of Beaver Creek, approximately 7.5 miles east of the Lewis Lake campground. Pre-1980: reported from "boggy areas by Beaver Creek" [exact date and location not known].	Wet willow thickets on mossy, hummocky terrain; occurs with *Eriophorum chamissonis*; elevation approximately 7,465 ft.	2 acres; second population occurs along Witch Creek, approximately 2 air miles to the west. 07-Jul-1997: Relatively abundant. Plants in flower or vegetative. 1997: Trail goes through population.	Wyoming Natural Diversity Database (2003)
10	Wyoming	Albany (or Carbon)	2004, 2005	Medicine Bow National Forest	Foxbourough Area north of Highway 230.	On "drier land" approximately 305 m (approximately 1,000 ft) away from a fen supporting a stand of *Eriophorum viridicarinatum* (thinleaf cottonsedge), *Picea glauca* (white spruce), *Salix barclayi* (Barclay's willow), *Lycopodium annotinum* (stiff clubmoss) and *Fragaria* sp. in the vicinity.	No flowers observed.	Proctor personal communication 2004, 2005; Roche personal communication 2004, 2005

[1]Herbarium abbreviations:

COLO: Herbarium, University of Colorado, Boulder, CO

RM: Rocky Mountain Herbarium, University of Wyoming, Laramie, WY analysis of the environmental impacts of federal activities whether in wetlands or terrestrial settings.

On National Forest System lands in Region 2, conservation strategies in place for *Rubus arcticus* ssp. *acaulis* include sensitive species status across the Region and monitoring studies on one national forest. The taxon does not occur on any lands with special status designations such as Research Natural Areas or Special Interest Areas. *Rubus arcticus* ssp. *acaulis* occurrences are known from the Pike and Arapaho national forests in Colorado and the Bighorn National Forest in Wyoming. The areas in which it occurs in the Bighorn National Forest and the Arapaho National Forest are primarily managed for recreation and/or livestock grazing. Recreation is emphasized in the area where it occurs in the Pike National Forest.

Because *Rubus arcticus* ssp. *acaulis* is designated a sensitive species, USFS policy is that the taxon be analyzed in biological evaluations that are carried out in advance of development projects on National Forest System lands. A biological evaluation includes field surveys and an analysis of the effects of the project on sensitive species. Field guides have been compiled for the Pike and San Isabel national forests to assist field staff in identifying rare and sensitive species. Two such publications that have included descriptions of *R. arcticus* ssp. *acaulis* habitat and morphology are by Kettler et al. (1993) and Ryke et al. (1993). Where feasible, sensitive species are protected from preventable disturbance. For example, the Arapaho National Forest flagged off an occurrence adjacent to a bridge re-construction site in 1997/1998 (Sumerlin personal communication 2004). *Rubus arcticus* ssp. *acaulis* plants in that vicinity were observed to be doing well in June 2004 (Sumerlin personal communication 2004). On the Bighorn National Forest in Region 2, monitoring studies on a population of *R. arcticus* ssp. *acaulis* are being conducted to assist in making biologically rational management decisions.

Within the contiguous lower 48 states of the United States but outside of Region 2, *Rubus acaulis* is designated as sensitive in the states of Michigan (USDA Forest Service Region 9) and Washington (USDA Forest Service Region 6). In Washington, *R. arcticus* ssp. *acaulis* occurs in the Okanogan National Forest, where it is not actively managed at the current time (Holmes personal communication 2004). In Michigan, it occurs in a candidate Research Natural Area (RNA) on the Hiawatha National Forest in the Upper Peninsula (USDA Forest Service 2002). One of the objectives in conveying RNA status is to protect the elements of biological diversity for which it was established. Since bog habitat is one of the elements considered important in this candidate RNA, management is particularly likely to conserve *R. acaulis* at this site. The recent Forest Plan (USDA Forest Service 2004b) recommended more specific direction for rare plants such as *R. arcticus* ssp. *acaulis*. In addition, this plan recommended that site-specific standards and guides be developed for established RNAs to help focus monitoring needs for these particular areas (USDA Forest Service 2004b).

Rubus arcticus ssp. *acaulis* is not considered rare in Minnesota because it is fairly common across the northeastern part of the state in conifer forest community types (Cholewa personal communication 2004). Although *Rubus arcticus* ssp. *acaulis* (reported as *R. acaulis*) is "present within proclamation boundaries of Region 9" (i.e., Chippewa and Superior national forests), it is not treated as a Regional Forester sensitive species because it has been determined not to be at risk (USDA Forest Service 2003b).

The wetland status of *Rubus arcticus* ssp. *acaulis* varies across its range (U.S. Fish and Wildlife 2005). USFS Region 2 includes parts of wetland regions 4, 5, 8, and 9 as designated by the U.S. Fish and Wildlife Service (USFWS). *Rubus arcticus* ssp. *acaulis* is designated an obligate (OBL) wetland species in wetland region 8, which includes western Colorado (USDA Natural Resources Conservation Service 2004; see **Definitions** section for more information on wetland regions). Under natural conditions, an obligate wetland species occurs almost always (an estimated probability of 99 percent) in wetlands. Many obligate wetland species occur in permanently or semi-permanently flooded wetlands, but a number of obligates also occur in, and some are restricted to, wetlands that are only temporarily or seasonally flooded (USDA Natural Resources Conservation Service 2004). In Oregon, Washington, western Montana, and western Wyoming, part of U.S. Fish and Wildlife Service wetland region 9, *R. arcticus* ssp. *acaulis* is designated a Facultative-plus (FAC+) Wetland species. A facultative wetland species is equally likely to occur in wetlands or non-wetlands (estimated 34 to 66 percent probability of occurring in wetlands). Facultative-plus species may or may not occur in wetlands, but they are most likely found in wetlands (USDA Natural Resources Conservation Service 2004). *Rubus arcticus* ssp. *acaulis* does not occur in wetland regions 4 and 5, and therefore it has no wetland indicator status in these areas. Outside Region 2, *R. arcticus* ssp. *acaulis* is designated as a wetland obligate in wetland region 3 (Michigan and Minnesota) and facultative (FAC) or facultative plus (FAC+) in the remainder of its range. There is insufficient information to determine the wetland status of this taxon in Maine (USDA Natural Resources Conservation Service 2004).

Where *Rubus arcticus* ssp. *acaulis* occurs in wetlands, it may be subject to a variety of federal laws, regulations, and policies. Section 404 of the Federal Water Pollution Control Act (Clean Water Act) of 1977 regulates certain activities in designated wetland habitats. This law requires avoidance of wetland impacts where practical or minimization or compensation of impacts if disturbance is unavoidable.

Two regional federal policy documents provide specific management direction for peatland habitats where *Rubus arcticus* ssp. *acaulis* occurs. The USFWS Regional Policy on the Protection of Fens (U.S. Fish and Wildlife Service 1998) designates functioning fens as Resource Category 1, meaning they are considered "unique and irreplaceable on a national basis or in the ecoregion." The mitigation goal of the policy is "no loss of existing habitat value." USFS Rocky Mountain Region Memo 2070/2520-72620, entitled Wetland Protection - Fens and signed by the Director of Renewable Resources, also gives regional guidance on fens. This memo informs forest supervisors of the USFWS policy and urges USFS personnel to "give careful consideration to avoiding impacts or identifying opportunities for restoration of these rare and irreplaceable habitats where they occur on National Forest System lands."

In Region 2, Watershed Conservation Practices guide management practices in and adjacent to wetlands (FSH 2509.25). These practices are designed to maintain ground cover, soil structure, water budgets, and flow patterns of wetlands.

Adequacy of current laws and regulations

The existence and use of these laws, regulations, and policies do not necessarily translate to adequate management and protection for *Rubus arcticus* ssp. *acaulis* or its habitat. No state or federal laws specifically relate to this taxon, and it is not legally protected on privately owned lands or on federal lands outside of the USFS.

While the laws, regulations, and policies mentioned above may benefit *Rubus arcticus* ssp. *acaulis* where it occurs in wetlands, protection in wetland habitats is not assured. For instance, the 2001 Supreme Court decision in SWANCC vs. U.S. Army Corps of Engineers (USACE) effectively removed regulatory oversight for wetlands lacking connections to surface water bodies such as streams (i.e., "isolated wetlands"). In general, Region 2 sites with *R. arcticus* ssp. *acaulis* are not considered isolated wetlands and continue to be subject to regulation under Section 404 (Carsey personal communication 2006). Any sites lacking surface connect to navigable waters of the United States and considered isolated wetlands would not be subject to Clean Water Act regulations.

Adequacy of enforcement of laws and regulations

The existence of protective laws, regulations, and policies is not necessarily sufficient to ensure adequate protection for *Rubus arcticus* ssp. *acaulis* and its habitat; in some cases, enforcement of these measures is inadequate or unpredictable.

- ❖ Compliance with the provisions of Section 404 of the Clean Water Act often is not attained, and compliance often is not monitored (National Research Council Committee on Mitigating Wetland Losses 2001).

- ❖ The USFWS Regional Policy on the Protection of Fens may decrease the likelihood that the USACE will permit peat mining under Section 404 of the Clean Water Act, but it does not prohibit application or granting permits.

- ❖ The U.S. Department of the Interior designation of peat as a commodity, renewable resource, and alternative fuel (USDI Bureau of Mines 1994, Secretary of the Interior 1994) appears to conflict with some of the policies and confuses the issue of enforcement.

- ❖ The U.S. Department of Energy promotes peat mining for energy by guaranteeing a market and by conducting research. By its designation as an alternative fuel, special tax incentives encourage major research, development, and construction investment.

- ❖ The USFS considers peat to be a saleable mineral (FSM 2822.1) in Region 2. The inherent loss of wetland habitat value associated with peat mining is in direct conflict with the Resource Category 1 designation of the USFWS as well as USFS Region 2 Watershed Conservation Practices.

Biology and Ecology

Classification and description

Systematics and synonomy

Rubus is a genus of the Rosaceae, commonly known as the rose family. *Rubus* was first described as such by de Tournefort and, shortly afterwards by Linnaeus in 1753 (Linnaeus 1753, Focke 1910). Species of the genus *Rubus* have a wide geographical distribution but are most abundant in the temperate zone (Britton and Brown 1970). The genus *Rubus* consists of about 250 sexual species and innumerable apomictic taxa (Mabberley 1997). Hybridization, polyploidy, and apomixes can complicate the taxonomy of *Rubus* (Gleason and Cronquist 1991). Britton and Brown (1970) described only 18 species in North America whereas Bailey (1941-1951) distinguished more than four hundred. Greater exploration may have contributed to the increase in number, but Bailey (1941) remarked that the paucity of whole specimens, especially those in good condition, has significantly hampered taxonomic studies. This may be equally true today.

Focke (1910, 1911, 1914) classified the world's *Rubus* into 12 subgenera: *Chamaemorus*, *Cylactis*, *Dalibarda*, *Chamaebatus*, *Comaropsis*, *Orobatus*, *Dalibardastrum*, *Malachobatus*, *Anoplobatus*, *Idaeobatus*, *Lampobatus*, and *Eubatus* (*Rubus*). *Rubus arcticus* ssp. *acaulis* belongs to the subgenus *Cylactis* (Focke 1910, Fernald 1950, Gleason and Cronquist 1991). Taxa in the subgenus *Cylactis* are characterized by having primarily herbaceous stems that are not well differentiated into primocanes and floricanes. They are also unarmed or only bear occasional weak bristles. Weber (1985) and Löve (1987) elevated *Cylactis* to genus level.

Michaux (1803) first described *Rubus acaulis* as a species, noting its affinity with *R. arcticus* but commenting that the two species were quite distinct. In his treatment, he referred to specimens collected from near the Hudson Bay, which are the type specimens for the taxon. Hultén (1946) made a thorough study of the *R. arcticus* complex and came to the conclusion that there were three species: *R. arcticus*, *R. stellatus*, and *R. acaulis* in Alaska and parts of Canada. He noted that these three species form a series connecting *R. arcticus* and *R. stellatus* on the one hand and *R. arcticus* and *R. acaulis* on the other. He also predicted that hybrids would be found between the species where they overlapped in range and may be very common in some locations. Hultén (1946) considered that *R. acaulis* should be strictly confined to those plants that are low-growing, have one-flowered stems, and whose flowers are essentially hairless on the hemispherical part of the calyx. This is in contrast to Bailey (1941) who accepted *R. stellatus* as a full species but considered *R. acaulis* in a wider sense. He referred to a "big-plant phasis usually called *R. arcticus*" and a "narrow-leaved phasis" of *R. acaulis* and considered all plants in North American and Kamtchatka to be *R. acaulis*, as distinct from the Eurasian *R. arcticus* (see **Definitions** section for an explanation of the term phasis). However, Bailey (1941) concluded that more taxonomic work was required and that critical collections from different patches or colonies across the continent were required. Hultén (1946) was convinced that the *R. arcticus* specimens from Alaska, especially from the western part, that he had examined were morphologically the same as the *R. arcticus* of Scandinavia. Boivin (1955) reviewed the sub-genus *Cylactis* and placed *R. acaulis* as a variety of *R. arcticus* ssp. *stellatus* (i.e., *R. arcticus* ssp. *stellatus* var. *acaulis*). He emphasized that the characteristics of var. *acaulis* were unique to the specimens he examined that were collected to "the east of the Mackenzie," presumably meaning in the eastern part of the Mackenzie Basin (Boivin 1955). He went on to report that it appeared that more variability, possibly evidence of hybrids, was common in the western part of the Mackenzie Basin (Boivin 1955). This observation supports Hultén's prediction of hybrid abundance in localized areas where the ranges of two species overlap.

Gleason and Cronquist (1991) included all North American species of the *Rubus arcticus* complex in *R. acaulis*. However, they noted that *R. acaulis* was closely related to the "chiefly Eurasian *R. arcticus* L., and possibly better treated as *R. arcticus* var. *grandiflorus* Lebed." Welsh (1974) considered it best to recognize only a single polymorphic species, *R. arcticus*, in Alaska and neighboring parts of Canada. Kartesz (1994) treated the taxon as a subspecies of *R. arcticus*.

Synonyms of *Rubus arcticus* ssp. *acaulis* include *Cylactis arctica* (L.) Raf.[2] ex B.D. Jackson ssp. *acaulis* (Michaux) W.A. Weber, *Manteia acaulis*

[2]Raf. is the abbreviation for the botanist C. S. Rafinesque-Schmaltz, Sm. for J. E. Smith, Ledeb. for C. F. von Ledebour, and L. for C. Linnaeus.

Raf., *R. acaulis* Michaux., *R. arcticus* var. *grandiflorus* Ledeb. and *R. arcticus* L. ssp. *stellatus* (Sm.) Boivin var. *acaulis* (Michaux) Boivin (Michaux 1803, Boivin 1955, Weber 1985, Kartesz 1994). *Rubus arcticus* L. var. *pentaphylloides* Hultén is synonymous with *R. arcticus* L. ssp. *arcticus* (USDA Natural Resources Conservation Service 2004).

Common names for *Rubus arcticus* ssp. *acaulis* include nagoonberry, northern raspberry, arctic raspberry, and bramble. It is also referred to as northern blackberry, which is a misnomer because the names blackberries and raspberries originally referred to distinctive fruit types. Within the genus *Rubus*, one characteristic separating the raspberries, such as *R. arcticus* ssp. *acaulis*, from the blackberries (subgenus *Rubus*) is that the fruit falls away from the dry receptacle in raspberries whereas the fruit is persistent on the fleshy receptacle of the blackberry (Britton 1901).

History of species

Linnaeus first described *Rubus arcticus* in 1753. Prior to his formal description, the plant was clearly described in several Scandanavian medicinal plant and horticultural books (Linnaeus 1753). Linnaeus (1753) reported that this species occurred in the Gulf of Bothnia region of Sweden, Siberia, and Canada. The first collection of *R. acaulis* appears to have been from the Hudson Bay area of Canada (Linnaeus 1753). In 1803, Michaux described *R. acaulis*, noting its affinity with *R. arcticus* but detailing its different characteristics. The specimens to which he referred were from spaghum bogs near the Hudson Bay, Canada (Michaux 1803). McTavish made the earliest collection from a more western part of Canada in 1853 from Churchill, Manitoba (Scoggan 1957). Within Region 2, the first collection appears to have been made from the Bighorn National Forest in Wyoming in approximately 1900 (**Table 1**).

The earliest description of the genus *Cylactis* was by Rafinesque-Schmaltz in 1819. In agreement with several current European researchers of *Rubus*, W.A. Weber elevated *Cylactis* to the genus level (Weber 1985).

Non-technical description

Rubus arcticus ssp. *acaulis* (**Figure 1**) is a diminutive, unarmed, rhizomatous, herbaceous perennial that is "almost stemless" (Porsild 1951). In fact, the Latin species epithet *acaulis* means stemless, referring to the lack of a tall woody stem (Soper and Heimburger 1982). In contrast to many *Rubus* species, *R. arcticus* ssp. *acaulis* has short (up to 10 cm [4 inches] and sometimes to 15 cm [5.9 inches]), upright flowering branches that lack prickles or bristles. The branches have two or three leaves and a solitary terminal flower on slender, finely pubescent peduncles. The flower has five pale-pink to deep rose-colored petals that are up to 2 cm (0.8 inches) long and are obviously narrowed towards the base. The sepals are lance-shaped and are up to 1 cm (0.4 inches) long. The calyx tube is hairless and glandless, and the calyx lobes are long-tapered and reflexed. The leaves are alternate, deciduous, and typically trifoliate but sometimes 5-foliate. The upper surface of the leaves is hairless and a dull green color whereas the underside is paler with minutely hairy margins. The terminal leaflet is stalked while the lateral pair are nearly sessile, asymmetrical, and often bear a partially developed lobe. The leaflet margins are serrate with blunt forward-pointing teeth. The fruit is an edible red raspberry (aggregate of drupelets) about 1 cm in diameter (description from Porsild 1951, Hultén 1968, Soper and Heimburger 1982, Fertig et al. 1994, Chadde 1999). Photographs of *R. arcticus* ssp. *acaulis* are shown in **Figure 2**.

Several characteristics distinguish subspecies *acaulis* from subspecies *arcticus* and subspecies *stellatus* (**Table 2**). Subspecies *acaulis* has narrow stipules, single flowers that are below the leaves, longer petals, and an absence of glands on the flower stems. In addition, according to Fernald (1950), the fruit of subspecies *acaulis* is also smaller with more numerous druplets than that of subspecies *arcticus* (Fernald 1950).

Rubus arcticus ssp. *acaulis* is superficially similar to *R. pubescens* (*Cylactis pubescens*) and species of strawberry, such as *Fragaria virginiana* and *F. vesca*. *Fragaria* species are common within *R. arcticus* ssp. *acaulis* habitat. Both *R. pubescens* and *Fragaria* species occur in Region 2 (Dorn 2001, Weber and Wittman 2001a, 2001b). *Rubus pubescens* has one to seven small white flowers per shoot. It trails extensively over the ground, the shoots have several leaves ultimately ending in slender whips, and the sharp-tipped leaflets have reticulate veins (Dorn 2001, Weber and Wittman 2001a and 2001b). *Fragaria* species also have white flowers but with 10 sepals and sepal-like bracts.

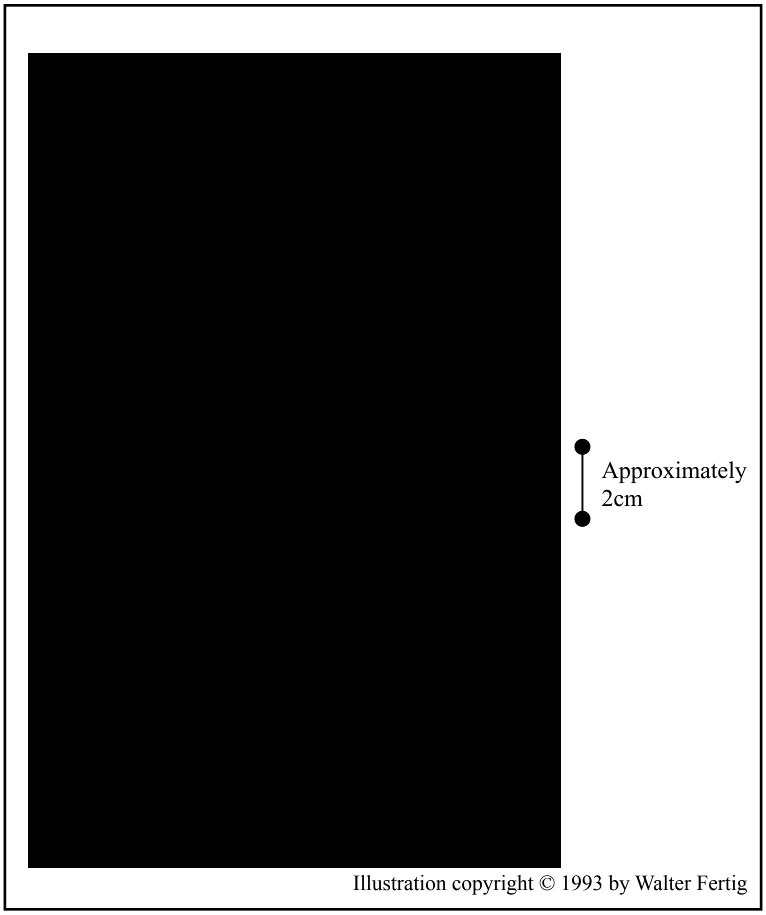


Figure 1. Illustration of *Rubus arcticus* ssp. *acaulis*. The scale was added to the illustration by J.A.R. Ladyman for this assessment. Illustration by Walter Fertig©, used with permission.

References to technical descriptions, photographs, line drawings, and herbarium specimens

There are many technical descriptions of this taxon. Descriptions under the name *Rubus arcticus* ssp. *acaulis* or *R. acaulis*, and differentiated from *R. arcticus*, include Hultén (1946), Fernald (1950), Porsild (1951), Hultén (1968), Porsild and Cody (1980), Soper and Heimberger (1982), and Douglas et al. (1999). Descriptions that submerge *R. acaulis* in *R. arcticus* include Britton and Brown (1970), Viereck and Little (1972), and Kershaw et al. (1998). Descriptions that refer to *R. acaulis*, but do not distinguish it from *R. arcticus* in North America, include Bailey (1941), Scoggan (1950), Scoggan (1957), Polunin (1959), Gleason (1963), Gleason and Cronquist (1991), and Hitchcock and Cronquist (2001). Boivin (1955) provides a technical description under the designation *R. arcticus* ssp. *stellatus* var. *acaulis*. A description and photograph of *R. acaulis* are published on the web site of the Michigan Natural Features Inventory (2005).

For the mid-Rocky Mountain States of Colorado, Wyoming, and Montana, technical descriptions of *Rubus acaulis* are in Harrington (1964), Dorn (1984), Dorn (2001), and Weber and Wittmann (2001a, 2001b), where it is treated as *Cylactis arctica* ssp. *acaulis*. In addition to the description, line drawings are in Bailey (1941), Porsild and Cody (1980), Soper and Heimburger (1982), and Douglas et al. (1999). A description, photograph, and line drawing are published in Fertig et al. (1994), Spackman et al. (1997), and on the web sites of the Colorado Natural Heritage Program (2005), and the USGS Northern Prairie Wildlife Research Center (Undated). A detailed description and a line drawing are also published on the Wyoming Natural Diversity Database website (2005). See the **References** section for these Internet site addresses.

Distribution and abundance

Rubus arcticus ssp. *arcticus* is a circumpolar, principally Eurasian species, whereas *R. arcticus* ssp. *acaulis* is restricted to North America and possibly

A)

B)

Figure 2. A) Photograph of a flowering *Rubus arcticus* ssp. *acaulis* on the Arapaho National Forest, Region 2. Photograph by John Proctor, USDA Forest Service, taken on July 15, 2005. **B)** Photograph of vegetative *R. arcticus* ssp. *acaulis* on the Pike National Forest, Region 2. Photograph by author, taken on June 26, 2004.

Table 2. Characteristics of *Rubus arcticus* subspecies (after Porsild 1951).

Characteristic	***R. arcticus* ssp.** *acaulis*	*arcticus*	*stellatus*
Leaf texture and color	Thin, dull green above, paler beneath	Thin, dark green on both sides, +/- shiny above	Rather thick, dull green above, paler beneath
Size terminal leaf	1.5-3 cm long, 1.5-2 cm wide	4-5 cm long, 3-4 cm wide	Not applicable - lobed rather than defined leaflet
Leaflet margin	Sharp serrate	Obtuse +/- double serrate	Obtuse +/- double serrate
Stipules	Lanceolate-linear, not prominent	Ovate, prominent	Lanceolate, prominent
Stem	Low, 5-10 cm high, almost stemless, flower hidden among leaves	Up to 30 cm high, slender, with 2-4 leaves	10-20 cm high, with about 3 leaves
Stem and petiole vestiture	Soft pubescent to glabrate, no stipitate glands	Glabrous to soft pubescent, occasionally with a few stipitate glands	Soft pubescent, always glandless
Flower	Single, 2-3 cm in diameter, claws narrow	One to two, 1.5-2 cm in diameter, claws broad	Single, 2-3 cm in diameter, petals broad, often retuse
Fragrance	None	Fragrant	Very fragrant
Sepals (collectively they comprise the calyx)	Narrow-attenuate, glabrous below, glandless	Attenuate-triangular, pubescent, =/- glandular	Triangular-attenuate, short pubescent throughout, glandless
Time of flowering (Canada)	Early	Late	Late
Fruiting (southeast Yukon)	Good	Poor	Sterile or poor
Habitat (Canada)	Lowland, general (widely distributed)	Alpine (relict type)	Alpine (relitc type)

Siberia. *Rubus arcticus* ssp. *acaulis* has been reported to be rare in Siberia, occurring infrequently in Kamtchatka (Hultén 1946). However, it has been omitted from more recent checklists for Kamtchatka (Charkewicz 1981, Koltzenburg personal communication 2004). Although a relatively widespread species, occurrences of *R. arcticus* ssp. *acaulis* are few and tend to be widely separated and particularly disjunct within the continental United States. Fernald (1925) included *R. acaulis* amongst the cordilleran flora that he perceived as primarily part of the western flora but which occurred in eastern North America. His concept suggested a migration from the West to the East. However, these *R. arcticus* ssp. *acaulis* disjunct populations within the continental United States most likely represent relic colonies that were left stranded as temperatures rose relatively rapidly at the end of the most recent glacial event, the Wisconsin glaciation, which ended around 10,000 years ago at the end of the Pleistocene epoch (Weber 1960, Daubenmire 1978, Davis 2003). Weber (1960) noted that *R. arcticus* ssp. *acaulis* appeared to be isolated in the more mesic mountain ranges in Colorado.

Rubus arcticus ssp. *acaulis* is often locally abundant throughout its range. However, because it is rhizomatous, the use of the term "individuals" to describe the composition of a population may not be accurate. Many plants that appear to be individuals may be linked by some degree of subterranean connection. The term "individual" tends to imply genetic uniqueness, but many individuals within a population may be ramets, or clones. The term individual stem is useful to describe an occurrence size, but it must be recognized that the numbers do not necessarily reflect independent plants or the genetic richness of the population.

Rubus arcticus ssp. *acaulis* is reported to grow in Alaska, Oregon, Washington, Colorado, Wyoming, Montana, Minnesota, Michigan, and Maine in the United States (NatureServe 2004). It has also been reported from many parts of Canada, including the provinces of Ontario, Quebec, Newfoundland Island, British Columbia, Labrador, Manitoba, Saskatchewan, and the territories of Northwest, Nunavut, and the Yukon (NatureServe 2004). Its presence in Oregon and

Maine needs to be confirmed. Although reported for the State of Oregon, *R. arcticus* ssp. *acaulis* is not on the draft checklist of vascular plant species for Oregon, and there are no specimens within the Oregon Herbarium network (Liston personal communication 2004, Oregon Herbarium Network 2005). *Rubus arcticus* ssp. *acaulis* is listed as occurring in Kennebec and Androscoggin counties in the Checklist of the Vascular Plants of Maine, but details of specimens were not given (Campbell et al. 1995). It is not listed in the Flora of Maine (Haines and Vining 1998), in the Flora of New England (Seymour 1969), nor are any specimens deposited in The University of Maine Herbarium (Campbell personal communication 2004, University of Maine Herbarium database 2004). *Rubus arcticus* ssp. *acaulis* was excluded from the Flora of Maine because "voucher specimens are unknown" and the taxon is "outside the known range of the species/subspecies" (Haines and Vining 1998).

Every effort was made to gather complete occurrence information for *Rubus arcticus* ssp. *acaulis* plants in the states that constitute Region 2. Outside of Region 2, the search was not exhaustive but probably represents a sizable proportion of the known occurrences. In **Table 1**, **Table 3**, and **Table 4**, an attempt was made to delineate an occurrence in accordance with NatureServe (2004) guidelines. It appears common that several suboccurrences constitute any given occurrence. An exception to this treatment is the record of occurrences in Ontario. Few specimens were located for this assessment, but many occurrences were reported in a distribution map constructed by Soper and Heimberger (1982). In this map there appeared to be 50 to 60 occurrences distributed across Ontario (Soper and Heimberger 1982). Occurrences 35-85 in **Table 3** denote these occurrences reported by Soper and Heimberger (1982). It must also be noted that many, particularly older, records do not have precise location information, and errors have likely been made in determining the exact number of occurrences. In some cases, a site may have been revisited and designated a new occurrence, or two or more discrete occurrences in the same general vicinity may have been estimated to be the same. In addition, the conditions of the specimens are not known, and poor specimens may have caused mistakes to be made in their identification. Another problem with identifying *R. arcticus* ssp. *acaulis* occurrences in Canada and Alaska is that sometimes subspecies were not considered and specimens may actually be *R. arcticus* or possibly even *R. stellatus*. For example, Wiggins and Thomas (1962) included all trifoliate leaved *Rubus* in *R. acaulis*. In the University of Alaska Museum Herbarium (ALA) of approximately 232 *R. arcticus* specimens, only 26 were identified as subspecies *acaulis* (University of Alaska Museum Herbarium 2005). Fourteen of those specimens were collected in Alaska (University of Alaska Museum Herbarium 2005). It is also notable that collections made from some areas, for example around Churchill in Manitoba, are in several herbaria, and it is not clear if such populations are relatively localized or widespread across a large area.

Five documented *Rubus arcticus* ssp. *acaulis* occurrences have been reported from Colorado and five from Wyoming. Eight of these ten occurrences are on land managed by USFS Region 2 (**Table 1**, **Figure 3**). Two occurrences are on the Pike National Forest and three are on the Arapaho National Forest in Colorado. Two occurrences are on the Bighorn National Forest and one is on the Medicine Bow National Forest in Wyoming (**Table 1**, **Figure 3**). The other two occurrences in Wyoming are in Yellowstone National Park. Observations at three occurrences in Colorado and four occurrences in Wyoming have been made since 1990. Some occurrence location information is vague and difficult to pinpoint on a map. For example, both occurrences 1 and 2 on the Pike National Forest are reported from Geneva Park (**Table 1**). The location directions for the occurrence 1 collection, which was made in 1966, were rather vague and may have referred to occurrence 2 or to an independent site, perhaps the Geneva Park Campground. Similarly, the two occurrences (occurrences 6 and 7, **Table 1**) in the Bighorn National Forest appear to be within a couple of miles of each other. However, occurrence 7 (**Table 1**) was reported in 1900 and may have been the same as occurrence 6 (**Table 1**) located in the late 1990's. The population represented by occurrence 6 consists of six or eight sub-populations scattered along a creek in areas of suitable microhabitat (Fertig 2000b, Karow personal communication 2004). Although plants are locally abundant, it appears that *R. arcticus* ssp. *acaulis* is restricted to this less than 2-mile stretch of Sourdough Creek. Extensive surveys during the 1990's were made for additional populations of *R. arcticus* ssp. *acaulis* within the Bighorn National Forest, but none were located (Fertig 2000b). A previously undocumented *R. arcticus* ssp. *acaulis* occurrence was reported in 2004 from the Medicine Bow National Forest in Wyoming (occurrence 10, **Table 1**).

Rubus arcticus ssp. *acaulis* is known from only one location in Michigan, in the Shingletown bog in the Hiawatha National Forest, Region 9 (USDA Forest Service 2002). It is also known from only one area, in the Okanogan National Forest (Region 6), in

Table 3. Summary of the available information for each *Rubus arcticus* ssp. *acaulis* occurrence site in Canada. Those occurrences with specimen verification are indicated in the column marked "Source."

Arbitrary occurrence no.	Dates observed	Province/ Territory	Location	Habitat and comments on plants observed	Source[1]
1	Jun-1925	Alberta	Waterton Lakes Parks, near golf course.	No information.	*M.O. Malte and W.R. Watson #244* COLO
2	08-Jun-1925	Alberta	Banff National Park. Vermillion Lake.	No information.	*M.O. Malte and W.R. Watson #944* COLO
3	10-Jul-1955	Alberta	Banff National Park. Foot of Mt Eisenhower.	Rich spruce pine forest at elevation at 4,500 ft.	*A. and D. Love #6664* COLO
4	10-Jun-1948	Alberta	Fallis.	In *Hypnum*-sedge area of bog.	*M.S. Moss. #s.n.* UWO
5	05-Aug-1977	British Columbia	East end of Fern Lake.	Grassy openings in *Picea glauca, Abies lasiocarpa* forest; elevation at 4,500 ft.	*G.W. Argus #10631* CAN, QK
6	30-Jul-1904	British Columbia	British Columbia – vicinity of Trans Canadian Highway.	Elevation at 6,200 ft. Flowers.	*E.L. Spencer #409* MO
7	early July 1967	British Columbia	Atlin Lake Region.	No information.	*J.H. Anderson #409* MSC
8	09-Jul-1966	British Columbia	Atlin Lake Region, Wright Creek road south from Surprise Lake, in vicinity of old mine.	3,700 ft. elevation.	*J.H. Anderson #203* MSC
9	29-Jul-1977, 31-Jul-1977	British Columbia	July 29: Peace River basin, slopes on north side of Robb Lake. July 31: Peace River Basin, north shore of Robb Lake.	July 29: Openings in *Picea engelmannii, Abies lasiocarpa* forest on steep south-facing slope at 3,900 feet. July 31: Wet *Salix* fen along lakeshore, with rich herbaceous flora.	*G.W. Argus and E Haber #10176* July 29 COLO, CAN; *G.W. Argus and E. Haber #10369* July 31 ALA
10	19-Jul-1981	British Columbia	Mosquito Flats, 4 miles east of Chilkat Pass and south of Nadahini Creek bridge, near Haines Hwy.	No information.	*J. & C Taylor #30806* MSC
11	04-Jul-1979	British Columbia	12 miles east on Spokin Lake Rd; southwest of Williams Lake.	*Picea glauca - Betula glandulosa - Sphagnum* forested wetland; subhydric; organic soils; 1,000 m.	*R. Coupé #s.n.* UBC
12	11-Jun-1980	British Columbia	Ahbau Lake Road; north of Quesnel.	Black spruce bog; subhydric; organic soils; elevation at 1,000 m.	*R. Coupé #s.n.* UBC
13	10-Jul-1981	British Columbia	Bridge Creek; south of Holden Lake; southwest of 100 Mile House.	Shrub fen; soil = Humic Mesisol; subhydric; elevation at 1,150 m.	*E. Dobyns #s.n.* UBC
14	13-Jul-1977	British Columbia	Between Two Lakes and Two Lakes Basin; South Chilcotin Mts.	Sedge meadow; elevation at 1,960 m.	*C. Selby #160* UBC
15	05-Jun-1979	British Columbia	West of Sheridan Lake, east of of 100 Mile House.	Wet bog; hydric; elevation at 1,097 m.	*A. Roberts #154* UBC

Table 3 (cont.).

Arbitrary occurrence no.	Dates observed	Province/ Territory	Location	Habitat and comments on plants observed	Source[1]
16[a]	06-Jun-1981	British Columbia	Cottonwood River, northeast of Quesnel.	*Picea glauca - Alnus incana - Matteucia struthiopteris* forest; sandy loam soil; subhygric soil; 7% slope grade; Northeat aspect.	*S. Taylor #s.n.* UBC
16[b]	01-Jul-1943	British Columbia	Vicinity of Sikanni River.	Wet mossy upland woods.	*H.M. Raup and D.S. Correll #10360* ALA
16[c]	18-Jun-1943	British Columbia	Vicinity of Beatton River.	Wet moss in muskeg.	*H.M. Raup and D.S. Correll #10115* ALA
17	1879	Manitoba	Churchill River.	No information.	*R. Bell #s.n.* QK
18	11-Aug-1959	Manitoba	Near Fort Churchill.	Growing in wet sand.	*W.T. Gillis #3378* MSC
19	05-Jul-1949	Manitoba	Fort Churchill.	An abundant species on the better drained, but still quite wet, gravel plain among white spruce at 9,918 ft. Flowers deep pink to red.	*W.G. Dore #9918* MSC
20	1949	Manitoba	Fort Churchill.	No information.	*A.S. West #40* QK
21	23-Jun-1970	Manitoba	Churchill vicinity.	Flowers.	*V. Love and J. Love #152* COLO
22	12-Jul-1953	Manitoba	Churchill.	Moist peaty soil.	*E. Beckett #s.n.* UWO
23	29-Jun-1976	Manitoba	Churchill, near Akudlik.	No information.	*W. Roff #s.n.* QK
24	12-Jul-1971	Manitoba	25 miles east of Churchill.	Marsh plant on moss mat.	*D.R. Service #31* QK
25	Jul-1880	Manitoba	Betweeen Oxford House and Echimamish River.	No information.	*R. Bell #s.n.* QK
26	Jul-1880	Manitoba	Between Oxford House and Knee Lake.	No information.	*R. Bell #s.n.* QK
27	05-Jul-1974	Manitoba	Knight's Hill.	Peaty ground on gravel esker.	*M.I. Heagy #s.n.* QK
28	27-Jul-1985	Manitoba	Hudson Bay, coastal area, moist esker.	No information.	*R. Harmsen #s.n.* QK
29	Early-mid Jul-1958	Manitoba	8 miles south of Sheridan.	On hummocks of Sphagnum in semi-dry bog at 350 m.	*D.O. Foster #s.n.* UWO
30	1947	Manitoba	Douglas.	No information.	Anonymous UWO
31	25-Jun-1971	Northwest Territories	On seismic line on the Mackenzie Delta proper, 1/2 mi. west of Tununuk Point.	Through 3-5 m tall willows.	*H. Hernanoez #222* CS
32	25-Jun-1969	Northwest Territories	Vicinity of McLeod Bay.	Snowdrift.	*R. Beschel #17307* QK
33a2	Jun-1885	Northwest Territories	Lake Mistassini.	No information.	*J.M. Macoun #s.n.* MSC
33b2	20-Jun-1939	Northwest Territories	Mackenzie Mts., north shore of Brintnell Lake.	In damp moss in woods on lakeshore. Flowers rose-pink.	*H.M. Raup and J.H. Soper #9179* ALA
33c2	12-Jun-1939	Northwest Territories	Fort Simpson.	Damp places in woods. Flowers magenta.	*H.M. Raup and J.H. Soper #9106* ALA
34	20-Jun-1984	Ontario	Sutton River Delta.	Dry tundra.	*S. Drzewieki #s.n.* UWO

Table 3 (cont.).

Arbitrary occurrence no.	Dates observed	Province/ Territory	Location	Habitat and comments on plants observed	Source[1]
35-85	Various (see text)	Ontario	50 to 60 occurrences from Hudson Bay and James Bay to north shore of Lake Superior and the Lake Timiskaming region.	In sphagnum mats, lichen heaths, arctic meadows, alder and willow thickets, black spruce and muskeg forests, on moist stream and river banks.	Soper and Heimberger (1982)
86	Prior 1959	Quebec	Mt. Logan, Shickshock Mtns, Gaspe Pennisula.	No information.	Unspecified collection(s) cited in Scoggan (1960)
87	Prior 1959	Quebec	Mt Blanc, Shickshock Mtns, Gaspe Pennisula.	No information.	Unspecified collection(s) cited in Scoggan (1960)
88	Prior 1959	Quebec	Rimouski, Gaspe Pennisula.	No information.	Unspecified collection(s) cited in Scoggan (1960)
89	Prior 1959	Quebec	Grand Riviere, Gaspe Pennisula.	No information.	Unspecified collection(s) cited in Scoggan (1960)
90	09-Aug-1905	Quebec	Mt Albert, Shickshock Mountains, Gaspe Pennisula.	Cool, mossy slopes at 950-1,050 m	*J.F. Collins and M.L. Fernald #102* MSC; unspecified collection(s) cited in Scoggan (1960)
91	02-Aug-1947	Quebec	Pres Hades Hills.	No information.	*J. Rousseau #689* RM; Herbarium of the Botanical Garden of Montreal
92	03-Jul-1939	Quebec	East coast of Hudson Bay. Cairn Island.	Generally distributed on present beach, old old elevated beaches and occassionally on moist arkose slopes approximately east of the Narrows.	*E.C. Abbe, L.B. Abbe, and J. Marr #3102* RM
93	24-May-1958	Saskatchewan	Crystal Lake.	Swamp near lake.	*C.H. Hood #26* QK
94	1919	Saskatchewan	Saskatoon Lake.	No information.	*Mrs. Russell #s.n.* QK
95	21-May-1973	Saskatchewan	Fond du Lac. On northeast shore of Lake Athabaska.	Bog.	*L. and L. Miller-Wille #73-29* COLO
96	1981	Saskatchewan	2 km west of Uranium City, north side of Lake Athabasca, east side Jean Lake, south of abandoned Cayzor-Atthabasca uranium mine operations.	On extensive minewaste rock pile toward NE end adjacent to black spruce woods. Locally abundant on moist gravelly rubble between larger rocks. Many showing 5-leaf tendency.	*V. L. Harms #31127* COLO
97	20-Jul-1974	Saskatchewan	Meadow Lake Provincial Park.	Edge of marshy area dominated by *Salix* just beyond beach ridge.	*Col. V.L. Harms #20497* RM, SASK
98	06-Aug-2000	Yukon	East side of Kimball Lake.Adjacent to fork of Dog Creek.	In rich moist herbaceous meadow. Collection represented an extension of range.	*B. Bennett #00-1107* DAO (Cody et al. 2002)
99	1974	Yukon	Old Crow Flats.	Bog at approximately 305 m (1,000 ft).	*J.A. Nagy with others #74-504* (Nagy et al.1979)
100	18-Jun- 1985	Yukon	Beaver River-Larsen Creek areas.	Marshy area underr shady mature spruce forest.	*B. Bennett #95-280a* DAO (Cody et al. 1998)

Table 3 (concluded).

Arbitrary occurrence no.	Dates observed	Province/ Territory	Location	Habitat and comments on plants observed	Source[1]
101	14-Jun- 1995	Yukon	La Biche River.	Small bog. Cody (1996) reported this species in Yukon only as far est as longitude 129W-these specimens extend range 275 km east. Cody (1996) reported this species in Yukon only as far east as longitude 129W-these specimens extend range 275 km east.	*B. Bennett #95-316b* DAO (Cody et al. 1998)
102	02-Jul-2000	Yukon	McCllusky Lake, Wind River.	In hummocky *Picea/Salix* forest near river. Collection represented an extension of range.	*B. Bennett #00-315* DAO (Cody et al. 2002)
103	12-Jul-2000	Yukon	Peel River, "Camp # 10" between Snake and Bonnet Plume rivers.	*Larix laricina/Picea mariana/ Sphagnum* marsh. Collection represented an extension of range.	*B. Bennett #00-697* DAO (Cody et al. 2002)
104	05-Jun-1949	Yukon	Whitehorse.	Clearing in spruce wood.	*W.W. Judd #s.n.* UWO
105	05-Aug-1944	Yukon	Mile 222 Canol Road, Ross River valley, near the north end Sheldon Lake.	No information.	*R.T. Porsild and A.J.J. Breitung #11563* ALA
106	01-Aug-1967	Yukon	Kluane National Park and Reserve. St. Elias Mts., northwest of Slims River, Kluane Lake.	No information.	*D. Murray and B. Murray #1237* ALA
107	01-Jul-1976	Yukon	Approximately 50 km west of Whitehorse.	Grassy open field halfway up mountain.	*S. Odsather #287* ALA
108	16-Jun-1985	Yukon	Whitehorse.	Wet marsh shore.	*M. Waterreus #s.n.* ALA
109	08-Jun-2000	Yukon	Kluane National Park and Reserve. St. Elias Mts., Alsek Trail.	No information.	*P. Caswell #494* ALA
110	23-Jun-1944	Yukon	Mile 1019 Alaska Highway, in vicinity of Pine Creek. Dezadeash Region.	Muskeg.	*H.M. Raup and L.G. Raup #11864* ALA

[1]Herbarium abbreviation:

ALA: University of Alaska Museum Herbarium, University of Alaska Fairbanks, Fairbanks, AK, USA
COLO: Herbarium, University of Colorado, Boulder, Colorado, USA
CAN: National Herbarium of Canada, Canadian Museum of Nature, Ottawa, Ontario, Canada
CS: Herbarium, Colorado State University, Fort Collins, Colorado, USA
DAO: Vascular Plant Herbarium, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada
MSC: Herbarium, Botany and Plant Pathology Dept., Michigan State University, East Lansing, Michigan, USA
MO: Herbarium, Missouri Botanical Garden, Saint Louis, MO, USA
QK: The Fowler Herbarium, Queen's University, Kingston, Ontario, Canada
SASK: W. P. Fraser Herbarium, University of Saskatchewan, Saskatoon, Saskatchewan , Canada
UBC: Herbarium, University of British Columbia, Vancouver, British Columbia, Canada
UWO: University of Western Ontario Herbarium, London, Ontario, Canada

[2]No relationship between occurrences followed by the same letter is implied; occurrences were added as information became available during publishing the assessment

Table 4. Summary of the available information for each *Rubus arcticus* ssp. *acaulis* occurrence site in the United States, excluding the states of Colorado and Wyoming. Those occurrences with herbarium specimens are indicated in the column marked "Source."

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
1	Alaska	Unknown	10-Jul-1981	Unknown	23 miles north of Juneau on island where St. Teresa Chapel is located.	No information.	*J. and C. Taylor #30679* MSC
2	Alaska	Mitkof Island	27-Jun-1981	Unknown	Near south end of Mitkof Island, 18 miles south of Petersburg, Alaska, near Blind River Rapids.	No information.	*J. and C. Taylor #30586* MSC
3	Alaska	Unknown	19-Jul-1944	Unknown	Near Gakona.	Woods.	*J.P. Anderson #203* MSC
4	Alaska	Unknown	1861	Unknown	Fort Simpson, USA.	No information.	*G.S. Crum Accession no. 37262* QK
5	Alaska	Kodiak Island	25-Jun-1939	Unknown	Lake Olga Bog District.	Meadow at shore of lake.	*E.H. Loof #s.n.* UWO
6	Alaska	Unknown	10-Aug-1947	Unknown	Canning River.	Boggy soils with considerable humus.	*R.L. McGregor #s.n.* MIN in Wiggins and Thomas (1962); *L.A. Spetzman #438* no date, AMES, MIN in Wiggins and Thomas (1962)
7	Alaska	Unknown	Undated	Unknown	Anaktuvuk Pass.	Boggy soils with considerable humus; [Tundra].	*L.A. Spetzman #1831* no date, MIN in Wiggins and Thomas (1962)
8	Alaska	Unknown	Undated	Denali National Park and Preserve	Denali National Park.	No information.	5 vouchered specimens reported in Lenz et al. (2001)
9	Alaska	Unknown	05-Jun-1985	Unknown	Tanana Lowlands, Willow Island.	Floodplain, open ground.	*M.J. Foote and E. Deehan #4862* ALA
10	Alaska	Unknown	3-Jun-1997	Lake Clark National Park and Preserve	Lake Clark, Port Alsworth.	Disturbed earth in village; flowers red.	*P. Caswell #97251* ALA
11	Alaska	Unknown	1-Jul-1985	Unknown	Kilbuck-Kuskokwim Mountains.	Waste areas.	*C.L. Parker #1369* ALA
12	Alaska	Unknown	16-Jul-1964	Unknown	Igloo Creek, West of Teklanika River, near bridge on Denali Park Road.	Roadside at Igloo Creek.	*A. Murie #17* ALA
13	Alaska	Unknown	30-Aug-1988	Tongass National Forest	Lynn Canal, north side of Skagway River.	South slope (midslope) of rocky alpine ridge.	*A. Batten and G.P. Juday #88-364* ALA
14	Alaska	Unknown	30-May-1989	Unknown	Blueberry Lake	Near lake edge; slightly wet, open area.	*S.L. Blatt, Jr. #89-30* ALA

Table 4 (cont.).

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
15	Alaska	Unknown	27-Jul-1996	Wrangell-St. Elias National Park and Preserve	Chugach Mountains, Granite Range, Bench east of Goat Creek.	Mesic tundra slope.	*A. Batten and M.H. Barker #96-203* ALA
16	Alaska	Unknown	26-Jul-1996	Wrangell-St. Elias National Park and Preserve	Ridge west of Nikolai Pass, south of Nikolai Creek in Wrangell Mountains.	Earthflow scar on steep south slope, rocks, gravels and fines all mixed up.	*A. Batten and M.H. Barker #96-156* ALA
17	Alaska	Unknown	7-Jun-1972	Unknown	Confluence of Salchaket Slough and Tanana River.	Spruce-birch woods.	*D. Simpson #s.n.* ALA
18	Alaska	Unknown	11-Jun-2003	Unknown	Kaskanak Creek drainage in the Nushagak-Kvichak lowlands.	Mesic heath shrub with scattered white spruce on low ridges along creek, herbaceous bank along creek margin.	*C.L. Parker #14026* ALA
19	Alaska	Unknown	15-Jun-2003	Unknown	Alaska Peninsula, Northwest shore of Iliamna Lake.	Gravel beach and silt-sand bluff at lake margin, growing at base of bluff.	*C.L. Parker #14151* ALA
20	Alaska	Unknown	10-Jul-2003	Cape Krusenstern National Monument	Kakagrak Hills, in the vicinity of the 'radio tower' airstrip.	Limestone barren uplands, snowmelt meadow.	*C.L. Parker, R. Elven, and H. Solstad #14548* ALA
21	Alaska	Unknown	12-Jul-2003	Cape Krusenstern National Monument	Omikviorok River valley, vicinity of 3 km northwest of VABM Agarok.	Lowlands with wet graminoid meadows, willow thickets, and hummocky shrub tundra, growing under willows.	*C.L. Parker #14639* ALA
22	Alaska	Unknown	29-Jun-2003	Glacier Bay National Park	St. Elias Mountains, Lower Alsek River, East Brabazon Ridge.	Alpine slope, scattered on thin organic layer over rocky diorite in forb-graminoid meadow on 20; east-facing slope, 95% vegetation cover.	*M. Carlson and S.D. Gisler #03-128* ALA
1	Michigan	Schoolcraft	17-Jun-1978	Hiawatha National Forest	String Bog, 1 mile south of Shingleton	Flowers pink, flowers rose colored.	*E.A. Bourdo #36107, #36108* MSC
2	Michigan	Schoolcraft	15-Jun-1977	Hiawatha National Forest	2.5 miles southwest of Shingleton.	Locally frequent in cedar swamp with black spruce and tamarack; flowers very fragrant with deep pink petals but with most plants past flowering.	*E.G. Voss #14949* MSC
1	Minnesota	Aitkin	11-Jun-1997	Savanna State Forest	Approx. 8.5 miles southeast of Hill City.	"Large tamarack swamp; on Sphagnum hummocks."	*L.B. Gerdes #2251* MIN

Table 4 (cont.).

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
2	Minnesota	Aitkin	16-Jun-1999	Savanna State Forest	DNR Releve 8029; may be part of Occurrence 1.	"Tamarack swamp with a continuous *Sphagnum* spp. moss carpet; associates: *Rubus pubescens, Betula glandulosa, Ledum groenlandicum, Lycopus uniflorus, Smilacina trifolia, Carex canescens, Calamatrostis canadensis*; soils: woody peat >1m deep."	*B. Carlson #00773* MIN
3	Minnesota	Aitkin	10-Jun-1997	Savanna State Forest	Approximately 1.5 miles southeast of Washburn Lake (east of Forest Road).	Tamarack swamp with *Carex chordorrhiza, C. tenuiflora, Alnus rugosa, Potentilla palustris*; on *Sphagnum* hummocks.	*L.B. Gerdes #2247* MIN
4	Minnesota	Beltrami	13-Jul-1975	Red Lake Wildlife Area	10.8 miles north of Waskish Post Office.	On *Sphagnum* hummocks, open bog, with *Potentilla fruticosa*, *Myrica*, etc.	*G.B. Ownbey #4974* MIN
5	Minnesota	Koochiching	31-Aug-1978	Red Lake Peatland State Natural Area	Approximately 10.5 miles north-northeast of the Waskish Airport and 8.5 miles east of Route 72.	Growing on the string of a patterned fen (minerotrophic area).	*P.H. Glaser #3378, G.A. Wheeler #3378* MIN
6	Minnesota	Beltrami	23-May-1978	Red Lake Wildlife Area	Approximately 14.5 miles north of the Waskish Airport on Route 72, about 0.5 mi west of the road.	Growing in a partially dried-up patterned fen.	*P.H. Glaser #2801; G.A. Wheeler #2801* MIN
7	Minnesota	Beltrami	08-Jun-1978	Red Lake Wildlife Area	Approximately 12 miles north of the Waskish Airport on Route 72, about 2 miles west of the road.	Growing on a string of a patterned fen (minerotrophic area).	*P.H. Glaser #2916; G.A. Wheeler #2916* MIN
8	Minnesota	Beltrami	23-May-1978	Red Lake Wildlife Area	Approximately 11 miles north of the Waskish Airport on Route 72, about 0.1 miles east of the road.	Growing on a string of the patterned fen (minerotrophic area).	*P.H. Glaser #2845; G.A. Wheeler #2845* MIN
9	Minnesota	Beltrami	11-Jun-1982	Red Lake State Forest	About 3 1/4 mi south of Waskish on the west side of Hwy 72.	Lowland woods dominated by *Thuja occidentalis* and *Sphagnum*, with *Listera cordata, Carex gynocrates, Smilacina trifolia*, and *Ranunculus lapponicus*.	*W.R. Smith #6274* MIN
10	Minnesota	Beltrami	10-Jun-1961	Red Lake State Forest	About 1 mile south of Waskish; just west of Highway 72.	In *Thuja-Sphagnum* bog on rotten logs and in moss.	*K.B.Kaul #s.n.*; *V. A. Heig #s.n.* MIN

Table 4 (cont.).

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
11	Minnesota	Beltrami	31-May-1991	Chippewa National Forest	Northeast of North Twin Lake.	In tamarack area of swamp; on hummock with *Vaccinium myrtilloides* and *Rubus pubescens*.	*NP Sather #91-78* MIN
12	Minnesota	Cass	10-Jun-1992	Chippewa National Forest	Located one mile northeast of Twin Lakes.	Plants growing in a swamp forest dominated by *Larix laricina* and *Picea mariana*; associated with *Menyanthes trifoliata* var. *minor*, Mitella nuda, and *Dryopteris carthusiana*.	*K.M. Myhre #2220* MIN
13	Minnesota	Beltrami	17-Jun-1979	Pennington Bog State Natural Area / Leech Lake Indian Reservation	Pennington Orchid Bog SNA, 1 mile north of Pennington.	Cedar bog.	*C. Keller #24* MIN
14	Minnesota	Beltrami	02-Jul-1982	Pennington Bog State Natural Area / Leech Lake Indian Reservation	Pennington Bog, 0.5 miles north of Pennington on east side of Rt. 36.	Arbor-vitae, larch, black spruce bog.	*G.B.Ownbey #6827* MIN
15	Minnesota	Cass	09-Jul-1993	Chippewa National Forest / Leech Lake Indian Reservation	Along Leech River; "few meters out of releve 93-18."	Rich fen *Carex lasiocarpa* var. *americana*; associated with *Dryopteris cristata* and *Galium labradoricum.*	*J.C. Almendinger #93070907*; *J.S. Boe #93070907* MIN
16	Minnesota	Cass	30-May-1991, 04-Jun-1993	Chippewa National Forest / Leech Lake Indian Reservation	1991: "Mad Dog Lake Bog". West of small upland island and Route 8. 1993: Mad Dog Lake Bog.	1991: In cedar swamp. 1993: Conifer swamp; stunted cedar with black spruce and tamarack. *Thuja occidentalis* and *Picea mariana*; associated with *Rubus pubescens* and *Caltha palustris*.	*R.M. Dahle #s.n.* 1991 MIN; *J.S. Boe #93060403* 1993 MIN
17	Minnesota	Cass	03-Jun-1993	Chippewa National Forest	Near Toqibue.	Conifer swamp; *Picea mariana* and *Thuja occidentalis*; associated with *Smilacina trifolia, Menyanthes trifoliata* var. *minor, Ledum groenlandicum*, and *Listera cordata*.	*J.S. Boe #93060301* MIN
18	Minnesota	Cass	23-Jun-1963	Chippewa National Forest	South of road, 3.8 miles east of road junction, 1 1/5 mile northwest of Boy River.	In *Sphagnum* hummocks of cedar swamp, with *Arethusa, Cypripedium, Calla, Ledum, Menyanthes, Smilacina trifolia, Caltha, Rhamnus alnifolia, Picea mariana, Thuja,* and *Cornus stolonifera*.	*T. Morley #1005* MIN
19	Minnesota	Cass	23-May-1972	Chippewa National Forest	Boy River Bog, 3 miles east of Boy River.	No information.	*E. Rathbun #s.n.*; *W.B. Rathbun #s.n.* MIN

Table 4 (cont.).

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
20	Minnesota	Clearwater	22-Aug-1962, 14-Jun-1978	Unreported	1962: About 5.6 miles due north of Clearbrook, route 5 1978: 5.5 miles north of Clearbrook along County Route 5, south side of marsh, west of highway.	1962: In marshy prairie of old lake bed. 1978: Tamarack bog, side of marsh.	*G.B. Ownbey #3437* and *W. L. Bloom #3437* 1962 MIN; *G.B. Ownbey #5860* 1978 MIN
21	Minnesota	Cook	20-Jul-1956	Grand Portage Indian Reservation/ North Shore	Along side of trail up Mt. Josephine, Grand Portage.	Along side of trail.	*H.M. Kellner #449* MIN
22	Minnesota	Itasca	06-Jun-1994	Chippewa National Forest / Leech Lake Indian Reservation	Located 0.7 mile southeast of Minisogama Lake.	Plants occur in a swamp forest dominated by *Thuja occidentalis*; associated with *Calypso bulbosa* var. *americana, Cypripedium reginae, Listera cordata*, and *Mitella nuda*.	*K.M. Myhre #4890* MIN
23	Minnesota	Itasca	08-Jul-1931	Unreported	South of Grand Rapids.	No information.	*J.S. Benner #s.n.* MIN
24	Minnesota	Koochiching	26-Aug-1997	Voyageurs National Park.	East Rat Root River Peatland SNA.	Black Spruce / Tamarack Swamp; *Thuja occidentalis, Carex letpalea* [sic], *Picea mariana, Larix laricina, Carex paupercula, Rubus acaulis, Betula glandulifera, Ledum groenlandicum,* and *Chamadaphane* [sic] *calyculata*.	*W.R. Smith #633* MIN
25	Minnesota	Koochiching	12-Jun-1984	Lost River Peatland State Natural Area	Sturgeon River Bog Complex, about 19 miles north of Northome.	Minerotrophic water track with string and flark patterns, with *Carex livida, Scheuchzeria palustris,* and *Triglochin maritima.*	*W.R. Smith #9055* MINN
26	Minnesota	Koochiching	12-Jun-1984	Lost River Peatland State Natural Area	About 23 miles north of Northome.	Fen-like peat dome with numerous sedge dominated channels running through a spruce swamp, in channels, with *Carex leptalea* and *Arethusa bulbosa*.	*W.R. Smith #9076* MIN
27	Minnesota	Koochiching	12-Jun-1984	Lost River Peatland State Natural Area	Forest Grove Peatland, about 9 miles north of Northome.	In sedge dominated water tracks which dissect a swamp forest, this is part of a “spring fen” system which is influenced by groundwater discharge, site dominated by *Carex lasiocarpa* and *Scirpus cespitosus*.	*W.R. Smith #9043* MIN

Table 4 (cont.).

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
28	Minnesota	Koochiching	16-Aug-1980	North Black River Peatland State Natural Area	North Black River Peatland, northwest of Loman and 27 miles west of International Falls; in Watershed II near Releve 25.	*Picea mariana* forest on raised bog; trees conspicuously clumped with occasional stumps of Christmas tree cuttings; continuous mat of *Sphagnum* with hummocks and hollows. pH 3.9, Ca2+ 0.9 mg1-1, etc.	*P.H. Glaser #1186* MIN
29	Minnesota	Lake	04–Jun-2000	Superior National Forest	Isabella; approximately 0.25 mile northwest of Tony Lake and 0.2 mile east of Hwy 1.	Poor black spruce swamp with *Picea mariana, Larix laricina, Ledum groenlandicum, Betula glandulifera, Alnus incana, Gaultheria hispidula, Calamagrostis canadensis, Kalmia polifolia* (in bloom), *Rubus pubescens*, etc.	*L.B. Gerdes #3942* MIN
30	Minnesota	Lake of the Woods	May-1928	Unreported	Near Baudette.	No information.	*H.H. Fadnes #s.n.* MIN
31	Minnesota	Lake of the Woods	17-Jun-1936	Unreported	Baudette.	No information.	*J. Manivelier #s.n.* and *J. Wentling #s.n.* MIN
32	Minnesota	Lake of the Woods	18-Jul-1936	Unreported	16 miles south of Baudette.	Drained bog; in a drying bog.	*J.B. Moyle #2180* (2 specimens); *C.O. Rosenthal #2180* (2 specimens) MIN
33	Minnesota	Lake of the Woods	30-Aug-1938	Unreported	Wheeler Township.	On hummocks in marshy ground.	*J.W. Moore #10379*; *M.F. Moore #10379* MIN
34	Minnesota	Lake of the Woods	12-Jun-1979	Beltrami Island State Forest	Brown's Lake.	In clumps on Sphagnum hummocks.	*J.S. Boe #109* MIN
35	Minnesota	Lake of the Woods	05-Jul-1979	Beltrami Island State Forest	Near Roosevelt Road northeast of Norris Camp.	*Larix laricina* stand.	*J.S. Boe #1749* MIN
36	Minnesota	Lake of the Woods	28-Jul-1939	Northwest Angle	Near the source of Pine Creek, Angle Inlet.	Growing in black spruce swamp.	*J.W. Moore #11223*; *M.F. Moore #11223* MIN
37	Minnesota	Lake of the Woods	13-Jun-1984	Mulligan Lake Peatland State Natural Area	Mulligan Lake Peatland.	Minerotrophic water track with string and flark patterns, and occasional wooded islands, at edge of water tracks, with *Carex diandra, Scirpus hudsonianus*, and *Equisetum fluviatila.*	*W.R. Smith #9142* MIN
38	Minnesota	Roseau	10-Aug-1983	Unreported	About 8 miles east of Strathcona on the south side of Hwy 6, near its junction with Hwy 3.	Sloping sedge meadow, with *Tofieldia glutinosa, Rubus acaulis, Parnassia glauca* and *Potentilla fruticosa.*	*W.R. Smith #8577* MIN

Table 4 (cont.).

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
39	Minnesota	Roseau	14-Jun-1984	Sprague Creek Peatland State Natural Area	Sprague Creek Peatland, about 12 miles north-northwest of Roseau (town).	In sedge dominated water tracks which dissect a swamp forest, part of a "spring fen" system influenced by groundwater discharge, dominated by *Cladium mariscoides* and *Scirpus cespitosus*.	*W.R. Smith #9195* MIN
40	Minnesota	St. Louis	31-May-1939, 04-Jun-1939, 10-Jul-1942, 25-May-1941	Unreported	Approximately 13 miles north of Duluth on Hwy 4.	May-1939: *Picea mariana* bog. Jun-1939: In *Picea mariana* bog, on *Sphagnum*. 1942: *Picea - Larix* bog.	*O. Lakela #4990* 1942; *O. Lakela #4327* 1941 MIN
41	Minnesota	St. Louis	06-Jul-1950	Unreported	Prairie Lake, Hwy 51, southwest St. Louis County.	In moss, alder swamp with *Sphagnum*.	*O. Lakela #10648* MIN
42	Minnesota	St. Louis	06-Jul-1953	Unreported	Prairie Lake area.	In deep sphagnum, spruce forest.	*O. Lakela #16169* MIN
43	Minnesota	St. Louis	10-Aug-1953	BWCA / Superior National Forest	Border of Lac La Croix, Beatty Portage	Cleared forest.	*O. Lakela #16767* MIN
44	Minnesota	St. Louis	07-Jul-1957	Unreported	Railroad right-of-way along Highway No. 7 between Sax and Fens.	#21446: Edge of peaty meadow; #21450: Peaty grass-dominated meadow, most plants scattered for miles in small colonies; # 21466: Peaty meadow	*O. Lakela #21463, #21450, #21464* MIN
45	Minnesota	St. Louis	20-Jun-1977	Superior National Forest	Plot G31. (Apparently in St. Lois Co. although reference to Lake Co.)	Black spruce-tamarack bog.	*N.P Sather #358* and *D. Shubat #358* MIN
46	Minnesota	St. Louis	28-Jun-1976	Superior National Forest	"Plot #16."	Spruce-tamarack bog.	*N.P Sather #141* and *D. Shubat #141* MIN
1	Montana	Beaverhead	24-Jun-1968	U.S. Fish and Wildlife Service - Red Rock Lake Wildlife Refuge	Red Rock Lake Wildlife Refuge.	*Salix* spp., *Carex* spp. at elevation 6,600 ft.; moderate abundance.	*R.D. Dorn #387* MONT
2	Montana	Flathead	28-Jun-1934	Glacier National Park	8 miles north of Fish Creek Ranger Station.	Wet mountain meadow; originally identified as *Rubus arctica*; notation suggests that it should be confirmed to be ssp. *acaulis*.	*B. Maguire #15824 and R. Maguire, C.B. Maguire* MONT
3	Montana	Flathead	Unknown	Glacier National Park	North half of Glacier National Park.	On hummocks in sphagnum fens. Known from three sites (Lesica 2002); unclear if the sites represent one or more populations.	Lesica (2002)

Table 4 (concluded).

Arbitrary occurrence no.	State/ Province	County	Date	Management	Location	Habitat and comments on plants observed	Source[1]
1	Washington	Okanogan	20-Jun-1988	Okanogan National Forest	In general vicinity of Tiffany Mountain region.	Growing on damp ground; associates: lone *Picea engelmannii*, *Salix* species, *Carex* species, *Sphagnum* and other mosses at 6,300 ft.	*E. Burnett #35* WTU

[1]Herbarium abbreviation:

ALA: University of Alaska Museum Herbarium, University of Alaska Fairbanks, Fairbanks, AK
AMES: Orchid Herbarium of Oakes Ames, Harvard University, Cambridge, MA
MIN: Herbarium - University of Minnesota, St. Paul, MI
MONT: Montana State University Herbarium, Bozeman, MT
MSC: Herbarium, Michigan State University, East Lansing, MI
WTU: Herbarium, University of Washington, Seattle, WA
UWO: Herbarium, Department of Biology, University of Western Ontario, Ontario, Canada

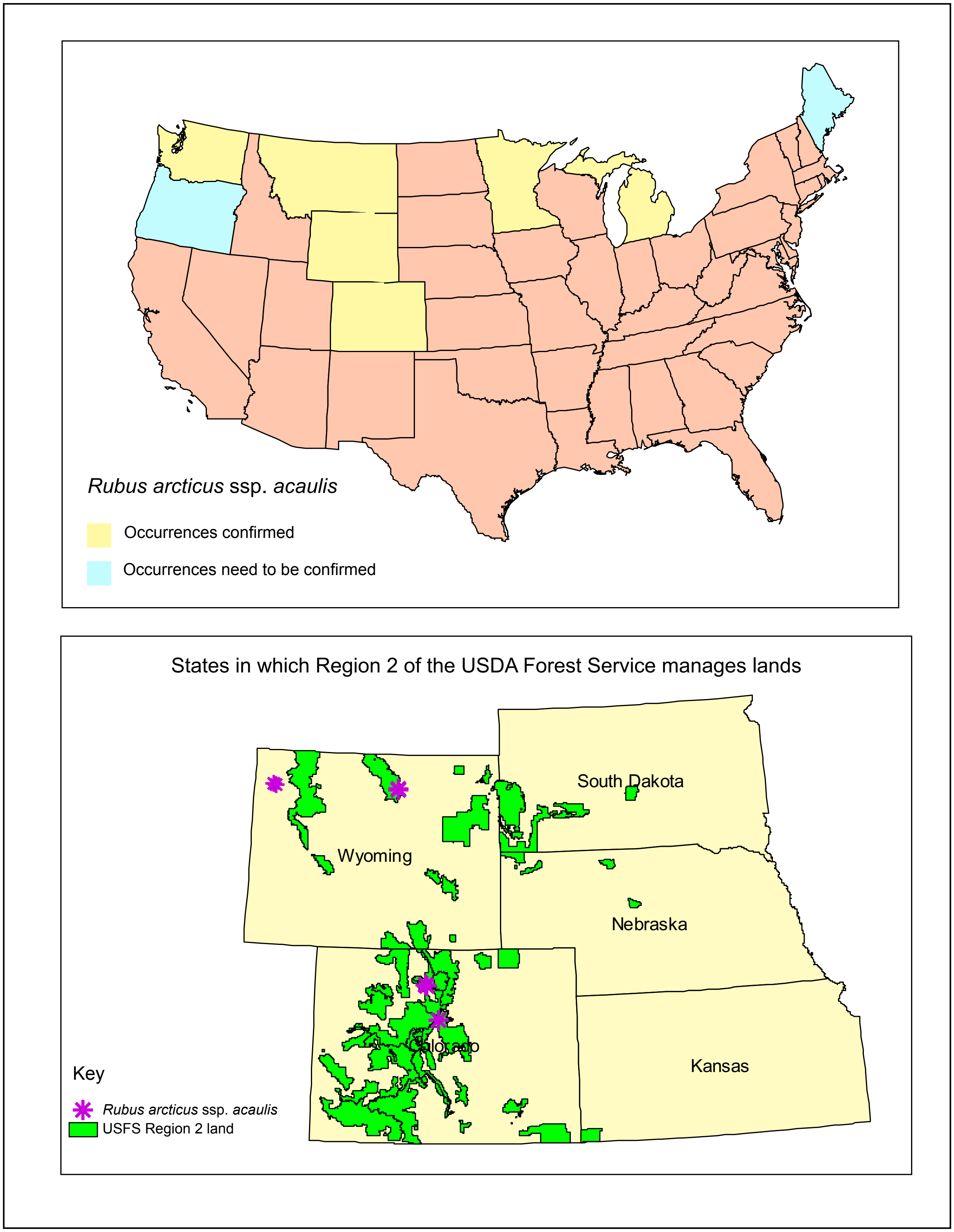


Figure 3. Range of *Rubus arcticus* ssp. *acaulis* in the continental United States and specifically in Region 2 of the USDA Forest Service.

Washington (**Table 1**). *Rubus arcticus* ssp. *acaulis* has been reported from Flathead and Beaverhead counties in Montana (Dorn 1984). Three occurrences in Montana have been documented, two in Glacier National Park and one in the Red Rock Lakes National Wildlife Refuge (Montana occurrences 1, 2, and 3 in **Table 4**).

Rubus arcticus ssp. *acaulis* has been reported from both the Superior and Chippewa national forests, Region 9, in Minnesota (**Table 4**). There are 55 *R. arcticus* ssp. *acaulis* specimens collected from Minnesota in the University of Minnesota Bell Herbarium, but several are actually duplicates made by separate members of the same collecting team. In addition, each specimen was not collected from a discrete area, and the number of occurrences in unique locations is reduced to approximately 46. The number of occurrences may be lower than the number indicated in **Table 4** because some of the location information was rather vague and occurrences were not combined if the location was likely to be independent. For example, Minnesota occurrences 11 and 12 may represent only one population; Minnesota occurrences 30, 31 and possibly 32 may represent a second population; and the occurrences north of Waskish (Minnesota occurrences 4, 5, 6, 7, and 8, **Table 4**) may be a third.

Rubus acaulis as a species designation has been used in both a wide and strict sense in Canada and Alaska (see Synonymy and systematics section). Therefore, its abundance is difficult to determine accurately from the records available. Cody et al. (1998) is one of the relatively few recent reports that describe collections made of both *R. arcticus* ssp. *acaulis* and *R. arcticus* ssp. *arcticus*. Soper and Heimburger (1982) reported at least 50 *R. arcticus* ssp. *acaulis* (as *R. acaulis*) occurrences in Ontario but noted that some of the material had two-flowered stems and some flowers had pubescent calices. In addition, no details were given on the time span over which the specimens were collected or the persistence at individual locations. *Rubus acaulis* appears common in some parts of Quebec, particularly the Gaspé Peninsula (Scoggan 1950). However, as in some other areas, Scoggan (1950) expresses some caution over identifying all specimens in this region as *R. acaulis*. In Manitoba, *R. acaulis* was described as occurring almost throughout the province (Scoggan 1957), but it appears that a large number of collections were made from the Churchill region where it was first collected in approximately 1853 (**Table 3**; Scoggan 1957).

Rubus arcticus ssp. *acaulis* occurrence data have been compiled from the Colorado Natural Heritage Program (2003), the Wyoming Natural Diversity Database (2003), Alberta Natural Heritage Information Centre, the British Columbia Conservation Data Center, specimens at the University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), The Rocky Mountain Herbarium (RM), The Fowler Herbarium at Queen's University (QK), University of Alaska Museum Herbarium (ALA), The University of Minnesota (MIN), Michigan State University Herbarium (MSC), The University of Western Ontario Herbarium (UWO), and from the literature (**Table 1**, **Table 3** and **Table 4**). An interactive map and further details of *R. arcticus* specimens in the University of Alaska Museum Herbarium can be accessed on their website (University of Alaska Museum Herbarium 2005).

Population trend

The data in the literature, associated with herbarium specimens, or at the state natural resource inventory programs are insufficient to determine the long-term trends over the entire range or even within land managed by USFS Region 2. Historical records of the abundance and range of *Rubus arcticus* ssp. *acaulis* are unavailable in most states and provinces.

Rubus arcticus ssp. *acaulis* has been documented on National Forest System lands in approximately eight locations within Region 2, but information on abundance, extent of occurrences, and number of genetic individuals is rarely available. In Colorado, an occurrence in the Geneva Park was located in 1966 (occurrence 2, **Table 1**) and possibly a different one (occurrence 2, **Table 1**) in 1979, 1995, and 2000. The author and Steven Olson (botanist with the Pike and San Isabel national forests) also briefly visited occurrence 2 on June 26, 2004. While this occurrence looked vigorous, no flowers were observed. Areas of similar boggy habitat, actually a continuation of the same meadow bog, were searched 1 mile and 1.8 miles to the north. The boggy meadow near the Geneva Campground may have been the area described in occurrence 1 (**Table 1**), but no plants were observed in 2004.

The number of populations and their persistence on the Arapaho National Forest in Region 2 is similarly ill defined. One well-documented population (occurrence 4, **Table 1**) occurs along Willow Creek, south of Willow Creek Pass, adjacent to the bridge to King Mountain Ranch (Sumerlin personal communication 2004). Occurrence 5, which was located in 1993 but has not been revisited, is not far from occurrence 4. Due to the imprecise location information, occurrence 3 may well refer to occurrence 4, or they may be both suboccurrences within the same population. Willow

Creek was also briefly visited in July 2005, and hundreds, approaching thousands, of aerial stems but only a few flowers were observed (Proctor personal communication 2005).

The site with the most information over the short term is occurrence 6 (**Table 1**) in the Bighorn National Forest. In 1994, two vegetative plants were first reported along Sourdough Creek. In June 1995, approximately six "small clumpy subpopulations" with two to 60 individuals were reported from Sourdough Creek. In July of the same year, thousands of individual stems were estimated along a 1.5-mile stretch of Sourdough Creek. This population was estimated at over 100,000 stems in 1999 (Fertig 2000b). The increase over the 5-year period is most likely explained by the more intensive surveys that were carried out, but environmental conditions may contribute to variable numbers of stems and leaves. Occurrence 7 (**Table 1**), reported in 1900, was apparently within a few miles of Sourdough Creek and may have been extirpated (see Distribution and abundance section).

Monitoring activities have been carried out on occurrence 6 in the Bighorn National Forest since 1999 (Fertig 2000b, Karow personal communication 2004). Changes in the frequency with which the taxon occurs in between 60 to 168 quadrat frames for six plots along Sourdough Creek between 2000 and 2004 have been recorded (see Monitoring section for more details). Three plots at the north end of Sourdough Creek, numbers 1, 1.5, and 2, were within 500 ft. of each other and may be considered as one sub-occurrence. They were more than 0.5 mile from plots 3 and 4, which were within 100 ft. from each other, and may be considered as a second sub-occurrence. Plot number 5 was the southern-most plot and is approximately 9,000 ft. from plots 3 and 4.

For three of the six plots (2, 3, and 4), no changes in frequency were detected. At plot number 1.5, an increase was detected between 2002 and 2003, but the frequency with which plants were observed within the quadrat frames declined to original levels between 2003 and 2004. The populations at these sites may be regarded as stable. Between 2000 and 2004, a significant ($p = 0.05$) decline in frequency was detected at plot 1 whereas plot 5 showed a steady increase in the proportion of quadrats in which plants were observed between 2001 and 2004. Overall, the population in Sourdough Creek appears to be relatively stable with year-to-year variation but with no significant trends detected. However, it must be remembered that both the spatial distribution and the density of a population influence frequency (Grieg-Smith 1983). Observing an increase in the proportion of quadrats in which a taxon is observed does not necessarily mean that the plants are increasing in density; the population may actually be becoming more sparsely distributed but shifting to cover more area. This may be in response to shifting resources or other environmental parameters. Therefore, frequency results are subject to various interpretations and should be considered for management purposes in conjunction with other details such as habitat conditions and observations on density and spatial distribution.

Outside of Region 2, there is little historical information on which to base estimates of trend. It appears that *Rubus arcticus* ssp. *acaulis* is a widespread species that is locally abundant and persistent at several sites (**Table 4**). On the other hand, it is a poorly understood taxon that has received little attention in many areas where it is locally abundant (see Distribution and abundance section).

A sobering consideration is that although *R. arcticus* ssp. *arcticus*, like the subspecies *acaulis*, is widespread and ranked G5, globally secure (NatureServe 2004), it is not uniformly so throughout its range and has suffered at least two extirpations. *Rubus arcticus* was native to Britain, and there are several records from the highlands of Scotland. However, it is currently believed to be extinct from the British Isles (Stace 1997). Similarly, *R. arcticus* is now extinct in Latvia (United Nations Economic Commission for Europe 1998, Latvian Environment Data Center 2000). Since 1958, *R. arcticus* has been listed as endangered in Estonia, and recent monitoring activity suggests it is still suffering a decline (Kukk 2001) and may even be in danger of extinction in the wild (Karp et al. 1997). Although still relatively common in Finland, *R. arcticus* is far less abundant than it was historically (Ryynänen 1973, Karp 1997, Schulman personal communication 2004). Although *R. arcticus* ssp. *arcticus* has a tendency towards apophysis (human activity helps its distribution), Karp (1997) points out that this is true only to a certain extent. Draining of suitable habitat, fire suppression, and a greater proportion of tall sedges, grasses, and trees in its meadow habitats have all contributed to its gradual decline (Karp 1997). The decline in these countries may also be due, at least in part, to the popularity of the berries for human consumption and the exploitation of peat for commercial purposes.

Habitat

Porsild and Cody (1980) described the habitat of *Rubus arcticus* ssp. *acaulis* as "not too dry, turfy places." Its habitat in Canada and Alaska has been only slightly more narrowly defined as "sedge meadows and bogs" (Viereck and Little 1974). These rather broad generalizations seem appropriate because it is difficult to define precisely the habitat for this taxon. Evidence suggests that *R. arcticus* var. *acaulis* typically grows in mesic conditions, and frequently in hydric soils. Latitude and/or elevation may influence habitat type since the taxon appears to be found in slightly different habitats depending upon its geographical location. Epitomizing the differences in habitat, *R. arcticus* ssp. *acaulis* is designated an obligate wetland species (OBL) in Michigan, Minnesota, and western Colorado, a facultative-plus (FAC+) wetland species in Oregon, Washington, western Montana, and western Wyoming, and only a facultative (FAC) wetland species in Alaska (USDA Natural Resources Conservation Service 2004; see Management section).

Region 2

In Region 2, *Rubus arcticus* ssp. *acaulis* grows in the montane and sub-alpine, at elevations between approximately 2,130 and 2,970 m (7,000 and 9,720 ft.). Vegetation types associated with *R. arcticus* ssp. *acaulis* include *Salix planifolia/Carex* [*rostrata*] *utriculata* (plainleaf willow/beaked sedge), and *Picea engelmannii/Linnaea borealis* (Engelmann spruce/ twinberry). In Colorado, *R. arcticus* ssp. *acaulis* grows in the upper montane willow zone (Weber 1960). This taxon has been reported to grow in boggy woods, marshes, mountain meadows, and alpine tundra (Fertig 2000a). Although clearly found in tundra in the northern parts of its range, there does not appear to be documented occurrences above the treeline in Region 2. In addition, although collection sites have been described as "boggy," the term might have been applied loosely when the collection site was actually a fen. Most, if not all, peatlands in the Colorado Rocky Mountains are fens (Cooper 1996).

The most recently found occurrence of *Rubus arcticus* ssp. *acaulis* in Region 2 was reported from the Medicine Bow National Forest in 2004. This occurrence was described to be on "drier land" approximately 305 m (1,000 ft.) away from a fen that supported a stand of *Eriophorum viridicarinatum* (thinleaf sedge) (Roche personal communication 2004). *Picea glauca* (white spruce), *Salix barclayi* (Barclay's willow), and *Lycopodium annotinum* (stiff clubmoss) were near this *R. arcticus* ssp. *acaulis* occurrence (Roche personal communication 2004). A species of *Fragaria*, likely *F. vesca* (woodland strawberry), was also a close associate (identified by the author from a photograph). Although none of these species are obligate wetland species, both *S. barclayi* and *L. annotinum* are most commonly found in moist sites (Wagner and Beitel 1993, Newsholme 2002). *Salix barclayi* is designated a facultative wetland (FACW) species, which is one that usually occurs in wetlands but is occasionally found in non-wetlands (USDA Natural Resources Conservation Service 2004). Although apparently drier than other *R. arcticus* ssp. *acaulis* sites within Region 2, this site is consistent with Porsild and Cody's (1980) observation that the habitat of *R. arcticus* ssp. *acaulis* was is in "not too dry, turfy places." Some of the species associated with *R. arcticus* ssp. *acaulis* in Region 2 are listed in **Table 5**. Available habitat descriptions for each of the occurrence sites in Region 2 are listed in **Table 1**.

The habitat of the *Rubus arcticus* ssp. *acaulis* occurrence at Willow Creek in the Arapaho National Forest in Colorado (occurrence 4, **Table 1**) is shown in **Figure 4**. The moist habitat of the population in the Pike National Forest in Colorado is shown in **Figure 5** and **Figure 6**. The non-vascular community at the site in the Pike National Forest (occurrence 2, **Table 1**) is very well developed and includes species of *Cladonia*, *Hypnum*, and *Spaghnum* (author's personal observation 2004). These habitat conditions are suggestive of the habitat in Ontario described by Scoggan (1950). Slopes on which *R. arcticus* ssp. *acaulis* grows at the macro-level are generally gentle, but the ground itself is often very hummocky. In 2004, species of *Salix* (willow) and *Betula glandulosa* (bog birch) were common at occurrence 2 (**Table 1**).

Given the geological formations that influence them, the soils or peatlands in the areas in which *Rubus arcticus* ssp. *acaulis* grows in Region 2 are unlikely to be alkaline. The regional geology heavily influences the character of the groundwater entering a fen, and groundwater flowing though granitic parent material is typically very nutrient poor and slightly acidic, having a pH value of approximately 6.5 (Cooper and Andrus 1994, Chimner and Cooper 2003). The geological formations under the Bighorn National Forest occurrences are glacial deposits and/or granitic gneiss with local migmatite formations, and they are thought to be volcanic in origin (Love and Christiansen 1985). Upper Miocene rocks of claystone and sandstone underlie the occurrence on the Medicine-Bow National Forest (Love and Christiansen 1985). The occurrence at Geneva Park in the Pike National Forest is underlain by gravels and alluviums and influenced by metamorphic rocks including biotitic gneiss, schist, and migmatite (Tweto 1979). The occurrence on the Arapaho National Forest is likely to be underlain by Arkosic sandstone

Table 5. Some of the vascular plant species associated with *Rubus arcticus* ssp. *acaulis* in Colorado and Wyoming. This is not a complete list and represents only those species that have been reported (for sources see **Table 1**).

Species name	Common name	Species name	Common name
Betula glandulosa	bog birch	*Linnaea borealis*	twinflower
Calamagrostis canadensis	reedgrass	*Pentaphylloides floribunda; Potentilla fruticosa*	shrubby cinquefoil
Carex aquatilis	sedge	*Picea engelmannii*	Engelmann spruce
Carex rostrata	sedge	*Pinus contorta*	lodgepole pine
Carex sp.	sedge	*Salix geyeriana*	willow
Deschampsia caespitosa	tufted hairgrass	*Salix lucida*	willow
Dodecatheon pulchellum	shootingstar	*Salix monticola*	willow
*Eriophorum chamissonis**	cottonsedge; bogwool	*Salix planifolia*	plainleaf willow
Fragaria sp.	strawberry	*Salix* sp.	willow
Fragaria virginiana	strawberry	*Thalictrum alpinum*	alpine meadowrue

*Associate in Wyoming; *Eriophorum chamissonis* is ranked Critically Imperiled, S1, in Colorado and Imperiled, S2, in Wyoming (NatureServe 2004).

and conglomerate containing abundant volcanic materials (Tweto 1979). Lack of calcareous sedimentary bedrock in many parts of the Rocky Mountains has produced peatlands mostly dominated by sphagnum mosses, rather than brown mosses that are characteristic of peatlands in calcareous areas that underlain by limestone (Chadde et al. 1988).

Outside of Region 2

In Manitoba, *Rubus arcticus* ssp. *acaulis* grows in boggy ground, wet woods, muskeg forest, and tundra (Scoggan 1957). It has been observed in woods, a marly bog at a river mouth, and alpine slopes in Quebec, where it has also been noted to preferentially colonize "granitic tundra-like tableland" (Scoggan 1950). In Ontario, *R. arcticus* ssp. *acaulis* grows on spaghnum mats and lichen heath of arctic meadows, in alder and willow thickets, in black spruce and muskeg, and on moist banks of streams and rivers (Soper and Heimburger 1982). In other Canadian provinces and in Minnesota, it is similarly found in hummocky bogs, marshes, and conifer (*Larix* spp., *Thuja* spp., and *Picea* spp.) swamps (**Table 3**, **Table 4**). *Rubus arcticus* ssp. *acaulis* is also reported from similar habitat in Alaska (**Table 4**). However, there are a few occurrences in Alaska that might be in drier habitats than those more frequently described (Alaska occurrences 10, 11, 12, and 13, **Table 4**).

Outside of Region 2, where *Rubus arcticus* ssp. *acaulis* has been reported to grow in water-inundated habitats, the taxon appears to favor peat bogs, which tend to have acid conditions. The pH of sphagnum moss peat ranges from 3 to 4.5 whereas that of decomposed sphagnum peat ranges from 5 to 7.5. One collection made in a calcareous alpine meadow in Quebec was initially identified as subspecies *acaulis* but was subsequently determined to have been more likely the subspecies *arcticus* (Soggan 1950). There is only one other collection location that was likely to be calcareous. A *R. arcticus* ssp. *acaulis* collection was made from "limestone barren uplands" in Alaska (Alaska occurrence 20, **Table 4**).

The report from Quebec (Quebec occurrence 34, **Table 3**) where *Rubus arcticus* ssp. *acaulis* grew in a dry meadow may actually have referred to a seasonally wet meadow because the evidence suggests that *R. arcticus* ssp. *acaulis* grows in wet conditions in Quebec. In addition, some areas defined as wetlands can be farmed, but if they are not tilled or planted to crops, which destroys the natural vegetation, they will revert to supporting hydrophytes (Cowardin et al. 1979). However, there is the possibility that local ecotypes that have adapted to different hydrological regimes have developed. Clearly more directed research is needed on the habitat requirements of *R. arcticus* ssp. *acaulis*.

Reproductive biology and autecology

Rubus arcticus ssp. *acaulis* is a perennial rhizomatous species that reproduces both vegetatively and by seed. In Region 2, flowering occurs from June to July (Spackman et al. 1997, Fertig 2000a), and fruits are present in late July and August (Spackman et al. 1997). Although Chadde (1998) reported that the flowering/fruiting period was between June and August

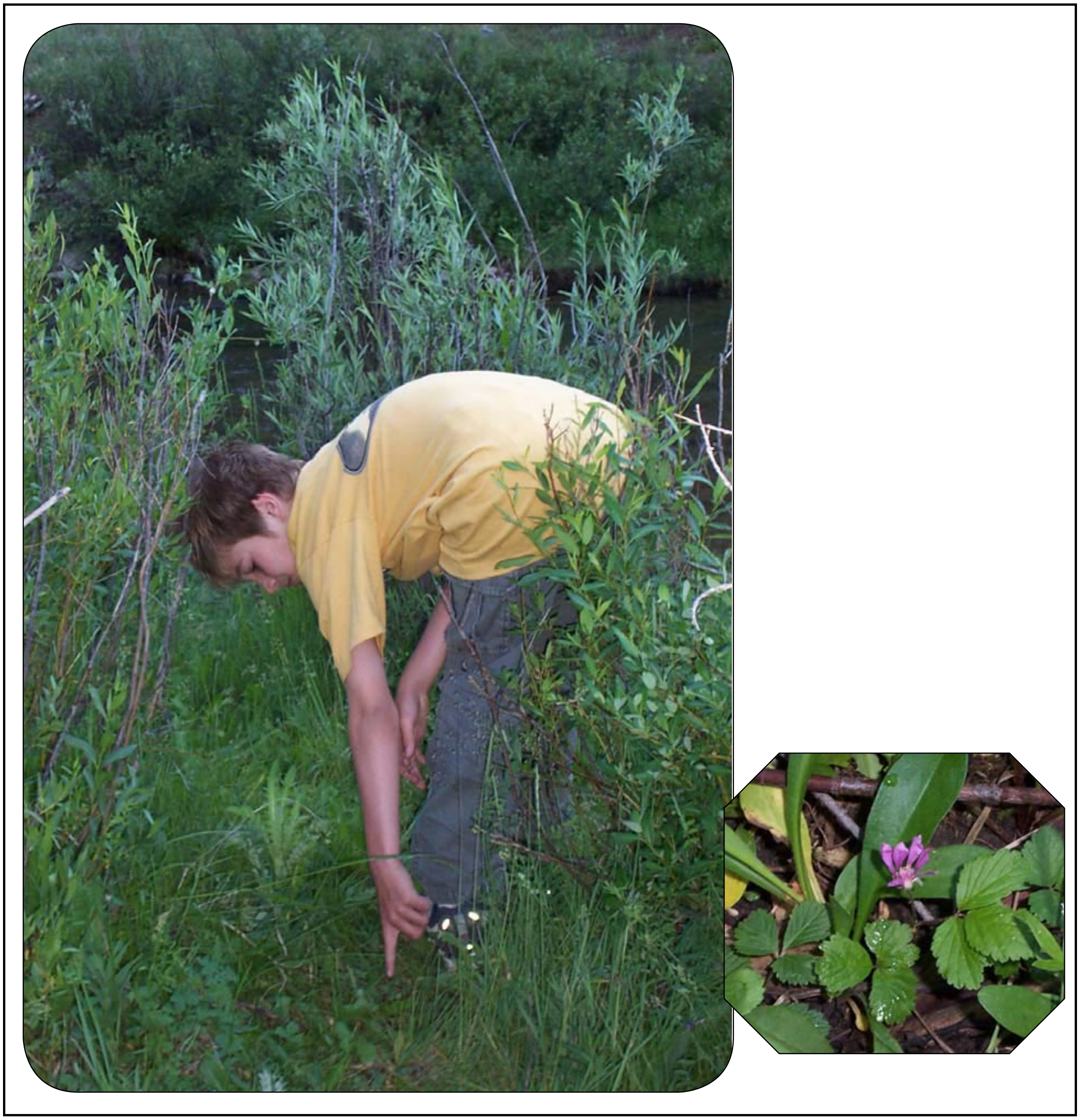


Figure 4. *Rubus arcticus* ssp. *acaulis* on the Arapaho National Forest, Region 2. The insert photograph shows a plant in flower. Photographs by John Proctor, USDA Forest Service.

for the Great Lakes region, blooming was noted to end approximately on 28 May in 1987 in Michigan (USDA Forest Service 2002).

Rubus is a reproductively interesting genus, and examples of self-fertilization, self-incompatibility, and apomixis are documented (Grant 1981). The subgenus *Rubus* (blackberries) in central Europe consists of numerous polyploid apomictic species, but the exceptions to this mode of reproduction are a few diploids (2n = 14) that show normal sexual reproduction (Weber 1995, Kollmann et al. 2000). Generally, all diploid *Rubus* species are believed to reproduce sexually. *Rubus* species have a haploid base chromosome number of x = 7, and *R. arcticus* ssp. *acaulis* is diploid, 2n = 14; the material that was used to determine the chromosome number for this taxon was from Manitoba, Canada (Löve 1987). Chromosome number from material taken from Alaska could not be determined due to insufficient material, but the length of the stomata and pollen size were consistent with a somatic chromosome number of 14 (Larsson 1969). *Rubus arcticus* ssp. *arcticus* from

© 2004 J.A.R. Ladyman

Figure 5. Photograph of the habitat of *Rubus arcticus* ssp. *acaulis* on the Pike National Forest, Region 2. Photograph by author.

Finland is typically diploid, 2n = 14, although one triploid population was identified (Tammisola 1988). Tammisola (1988) attributed this population's lack of fruit production to this triploid condition.

There is little detailed information specifically on the reproductive strategy of *Rubus arcticus* ssp. *acaulis*. Its flowers are reported to be hermaphroditic, self-incompatible, and insect-pollinated (USDA Forest Service 2002). However, the extent to which they are self-incompatible is likely inferred from studies on *R. arcticus* ssp. *arcticus* in Europe (Tammisola and Ryynänen 1970, Tammisola 1988). The extensive crossing experiments made by Tammisola (1988) suggested that self-incompatibity was universal amongst the Finnish populations of *R. arcticus* ssp. *arcticus*. Harper (1977) commented that a clonal growth habit is usually tightly linked with strict out-breeding (dioecy or self-incompatibility) and the well-developed clonal reproduction through rhizomes is consistent with *R. arcticus* ssp. *acaulis* being an obligate out-crosser. However, at this stage, the possibility that self-compatible populations of *R. arcticus* ssp. *acaulis* exist cannot be ruled out.

The self-sterility system of *Rubus arcticus* ssp. *arcticus* is caused by gametophytic self-incompatibility controlled by a single gene locus (Tammisola 1988). Therefore, two *R. arcticus* ssp. *arcticus* clones with a common genotype with respect to the incompatibility locus cannot fertilize one another. Tammisola (1988) observed experimentally that lack of fruit set was almost always due to ramets of only a single incompatibility class being present. For high fruit set, the presence of at least three equivalence classes of incompatibility was required (Tammisola 1988). Equivalence class refers to the combination of the two alleles at the gene locus that influences incompatibility (Tammisola 1988). If this is true for *R. arcticus* ssp. *acaulis*, then gametophytic incompatibility may be a serious concern in isolated populations.

Figure 6. Photograph of the habitat of *Rubus arcticus* ssp. *acaulis* on the Pike National Forest, Region 2. Photograph by author.

Adequate suitable pollinators are frequently critical to the long-term sustainability of out-crossing taxa (Bond 1995, Buchmann and Nabhan 1996, Kearns et al. 1998). Bumblebees (*Bombus* species) and honeybees (*Apis mellifera*) are reported to be the pollinators of *Rubus arcticus* ssp. *arcticus* (Ryynänen 1973, Kangasjarvi and Oksanen 1989). Tamminsola (1988) commented that, in general, bumblebees did not visit *R. arcticus* ssp. *arcticus* very often. In studies that compared the number of visits made by various bumblebee species to 100 food plant species, it did not appear that bumblebees particularly favored *R. arcticus* ssp. *arcticus* (Tamminsola 1988). Tamminsola (1988) proposed that only specialized bumblebee species used *R. arcticus* ssp. *arcticus* to a substantial extent. For example, the long-tongued *B. hortorum* was not interested in the short-corolla *R. arcticus* ssp. *arcticus* flowers whereas *B. soroeensis* did visit *R. arcticus* ssp. *arcticus* regularly, although relatively infrequently (Tamminsola 1988). Only honeybees were observed to visit flowers of *R. arcticus* ssp. *acaulis* in the Bighorn National Forest in 1999 (Fertig 2000b). If bees are the primary pollinators, a paucity of flowers at individual occurrences may contribute to low pollination success. Bees, unlike several other flower visitors, are density-dependent foragers (Heinrich 1976). As well as total number of flowers in an area, the size of a mat may also influence the frequency with which cross-pollination occurs. Bumblebees appeared to visit preferentially large, rather than small, clumps of *Astragalus canadensis* in an Iowa prairie (Platt et al. 1974). Conversely, if flower numbers are adequate for pollinator visits, then spatially disjunct groups of plants may have high levels of dispersal and gene flow between them. Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m (range 70 to 631 m) from the nest to forage even when ostensibly plentiful food was available nearby. Honeybees can regularly forage 2 km away from their hive (Ramsey et al. 1999). This suggests that occurrences within at least 200 m, and most likely further, are exchanging genetic material to some degree. In Europe, the berry production of *R. arcticus* frequently appears to be limited by a lack of pollinators (Ryynänen 1972, Tammisola 1988). Bees preferred white clover (*Trifolium repens*), strawberries (*Fragaria* species), and dandelions (*Taraxacum species*) to *R. arcticus* ssp. *arcticus* in Finland (Kangasjärvi and Oksanen 1989).

The *Rubus arcticus* ssp. *acaulis* populations in Colorado and Wyoming are reported to produce few flowers and very few to no fruits (Spackman et al. 1997, Fertig 2000b). Extrapolating information from studies on *R. arcticus* ssp. *arcticus*, there are at least three reasons to explain this lack of fruit: (1) the non-fruiting populations may be triploid, (2) populations may be composed of clones that represent only one or two incompatibility genotypes (equivalence classes), or (3) populations may be pollinator limited.

If a sub-occurrence originated from fewer than five seeds or possibly only one seed and little sexual reproduction occurs, the sub-occurrence may persist but remain composed of only one or a few genetically unique individuals. Given the local abundance reported for the occurrences in Region 2, this might appear unlikely, but one clone of *Rubus arcticus* ssp. *arcticus* can be very large and long-lived. Tamminsola (1988) identified a clone that covered an area of 80 m in diameter, and he estimated, from a growth rate of 25 cm per year lateral expansion, that it was approximately 160 years old. He was not searching for particularly large individuals and sampled relatively few plants; therefore, he noted that much larger clones might be found. If this size is common for ssp. *acaulis*, then the three monitoring plots, #1, #1.5, and #2, on the Bighorn National Forest may encompass very few genetically unique individuals (see Population trend section).

Porsild and Cody (1980) described the flowers of *Rubus arcticus* ssp. *acaulis* as fragrant. However, Porsild (1951) described the flowers as being scentless in contrast to the flowers of ssp. *arcticus*, which are very fragrant. It may be significant that some flowers of ssp. *acaulis* are essentially scentless. Scentless flowers can be cross-pollinated, but pollinators may visit them less frequently than scented individuals (Mosquin and Martin 1967). Visitation frequency will be most affected when there are many other host flowers that provide competition (e.g., *Trifolium* spp. [clovers]). Since scentless flowers are less attractive to insects, Mosquin and Martin (1967) suggested that loss of scent might be associated with loss of pollinator dependence and perhaps self-compatibility.

Habitat may also influence flower production. On the Bighorn National Forest in 1999, 24 to 39 percent of the *Rubus arcticus* ssp. *acaulis* stems were in flower within sub-populations that were in willow thicket/sedge marsh habitat while 23 to 27 percent were in flower within the sub-populations in forested areas (Fertig 2000b). It is well known that shade can influence flowering frequency in some genera. The statistical significance of the difference in flowering rate was not tested.

Porsild and Cody (1980) commented that *Rubus arcticus* fruits are red, small, and sweet. The fruit is palatable and has been highly prized by humans, although reportedly the European subspecies *arcticus* tastes better that the North American fruits (Ryynänen 1972). Therefore, various animals, including rodents and birds, will contribute to seed dispersal. Spring floods also disperse *R. arcticus* ssp. *arcticus*' seeds in riverside habitats (Tammisola 1988).

The frequency with which *Rubus arcticus* ssp. *acaulis* seed germinates has not been documented. The rate of seed recruitment to the seed bank, seed longevity in the soil, and the extent of seed predation for *R. arcticus* ssp. *acaulis* are also all unknown. In cultivation, *R. arcticus* ssp. *acaulis* seed requires stratification and is best sown in early autumn in a cold frame (Plants for a Future 2004). Stored seed requires a one-month stratification period at about 3 °C and is best sown as early as possible in the year (Plants for a Future 2004). In cultivation, seedlings should be pricked out when they are large enough to handle and grown in a cold frame until planted out into their permanent positions in late spring of the following year. Division of established plants should take place in early spring or just before leaf-fall in the autumn (Huxley 1992).

Relative to other species, *Rubus* species' seed are generally naturally abundant in the seed bank (Thompson 1992). The pulpy coat of the raspberry may provide germination inhibitors that would require a certain period of time in the soil to dissipate (Baskin and Baskin 2001). The seed coat is also thick and hard (Tammisola 1988). *Rubus arcticus* ssp. *arcticus*' seeds, like those of many *Rubus* species, can remain viable in the soil for many years (Granstrom 1987, Tammisola 1988). The germination rate of *R. arcticus* ssp. *arcticus* is low, usually less than 40 percent (Ryynänen 1973). *Rubus arcticus* ssp. *acaulis* may be similarly adapted to retain the majority of its seeds ungerminated in the ground for a long time, germinating sporadically when suitable conditions occur. *Rubus arcticus* ssp. *arcticus*' seeds were reported to germinate well in burned fields in Scandinavia (Tammisola 1988). It is not clear if the buried seeds were responding to a decrease in vegetation canopy, a reduction in plant competition, the transient increase in available nitrogen, or some other physiological condition.

No evidence of hybridization between *Rubus arcticus* ssp. *acaulis* and other sympatric species has been reported in Region 2. However, hybridization is common among *Rubus* species. Although particularly common among the blackberries, subgenus *Rubus*, it has been well documented amongst the (sub)-genus *Cylactis* (Hultén 1946, Boivin 1955). Apparent hybrid swarms of *R. arcticus* ssp. *acaulis* with subspecies *arcticus* and subspecies *stellatus* are reported from Alaska (Hultén 1968). *Rubus propinqus* and *R. paracaulis* were speculated to be hybrids between *R. arcticus* and *R. pubescens* (Bailey 1941, Scoggan 1957, Scoggan 1978).

Demography

Rubus arcticus ssp. *acaulis* is a rhizomatous perennial that reproduces asexually from rhizomes and sexually by seed. Its underground structure has not been studied in detail but is likely quite extensive. The underground structure of *Rubus arcticus* ssp. *arcticus* has been well studied in Finland. The rootstock is much branched, horizontally spreading, and has the ability to develop adventitious buds that develop into shoots. The root system covers an area of several meters (Ryynänen 1972). Tammisola (1988) reported clones of ssp. *arcticus* spreading across areas of approximately 80 m in diameter. The horizontal roots grow at a depth of 3 to 5 cm, but smaller feeder roots, less than 1.5 mm diameter, arise from the horizontal roots and grow downward as well as laterally (Ryynänen 1972). These roots may reach a depth of 30 to 40 cm (Tammisola 1988). However, it should be remembered that these measurements were made for subspecies *arcticus*, which has aerial stems two to three times longer than subspecies *acaulis*.

Populations of *Rubus arcticus* ssp. *acaulis* in Colorado and Wyoming have been reported to produce relatively few flowers and even fewer fruit (Spackman et al. 1997, Fertig 2000, Sumerlin personal communication 2004). In 1999, 23 to 39 percent of stems were in flower, but there was no fruit production by the population on the Bighorn National Forest (Fertig 2000b). The populations on the Arapaho and Pike national forests are also mostly vegetative. Therefore, in the Rocky Mountains of Region 2, reproduction may be predominantly through clonal propagation.

Little information is available specifically on the demographics of *Rubus arcticus* ssp. *acaulis*. The age and structure of a population is particularly difficult to assess. As Fertig (2000b) noted, accurately determining the number of individual plants is extremely difficult without destructive sampling. It needs to be noted that phenotypic plasticity is extensive amongst *Rubus* species, and morphological features have not proved to be indicative of genetic variation (Nybom and Schaal 1990). Studies on the genetics of *R. arcticus* ssp. *acaulis* populations are needed to better understand this species. However, isozyme analysis, which is often a relatively easy and reliable tool for detecting genetic variation, has not been proven to be very successful for *Rubus* species, and only DNA minisatellite analysis proved effective in differentiating different genotypes (Nybom and Schaal 1990). More recently, subspecies (ssp. *stellatus* and ssp. *arcticus*) and cultivars of *R. arcticus* were clearly distinguished from each other based on amplified fragment length polymorphism (AFLP) marker data (Lindqvist-Kreuze et al. 2003).

The proportion of seedlings in *Rubus arcticus* ssp. *acaulis* populations is unknown. It is difficult to distinguish between small clonal offspring and seedlings after the initial germination event. There is no knowledge of the number of aerial stems per rhizome. In addition, it is likely that the number of aerial stems will vary from year to year in response to environmental conditions and will not always reflect the size of the belowground population. This rhizomatous growth habit suggests that the patches observed over an area may be derived from one or at most only a few individuals. In addition, the paucity of flowers and fruits leading to low rates of sexual reproduction supports the theory that there are likely to be few genetically unique individuals in an occurrence. Patch dynamics of *R. arcticus* ssp. *acaulis* or the dynamics of the individuals within the patches have not been investigated. The reason for the very localized nature of populations, such as that in the Bighorn National Forest in Region 2, is not known (see Distribution and abundance section).

Transition probabilities between the different stages, from seed production to the flowering adult are unknown. A simple life cycle model of *Rubus arcticus* ssp. *acaulis* can be described in diagrammatic terms (**Figure 7**). Heavy arrows indicate phases in the life cycle that appear most prominent, and lighter weight arrows indicate the phases that are either apparently

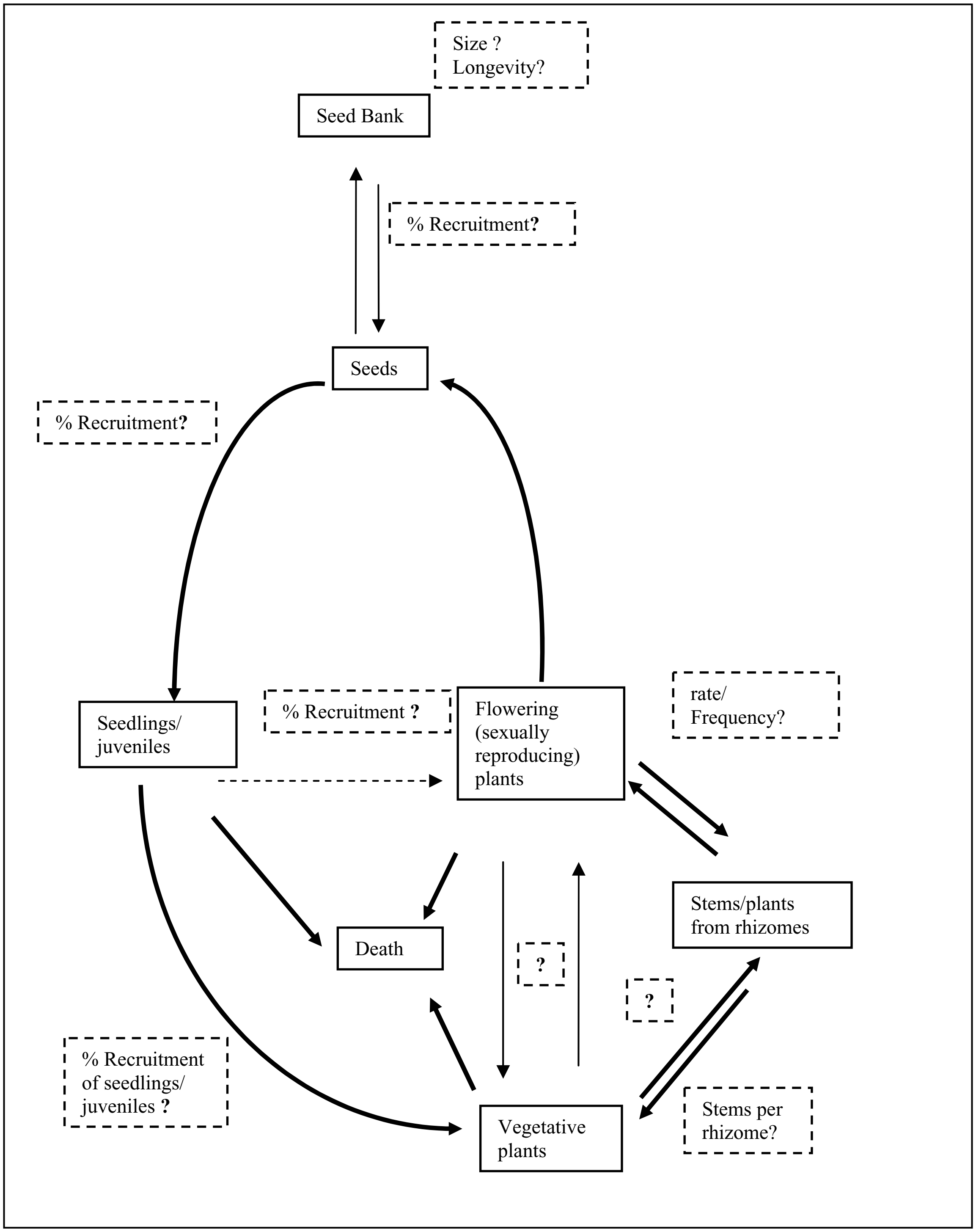


Figure 7. A proposed life cycle diagram for *Rubus arcticus* ssp. *acaulis*.

less significant or unknown. The steps that particularly need to be clarified are noted by a "?" at the appropriate arrow. Although more information is needed to define which of the life history stages have the greatest effect on population growth and survival, it can be speculated that the rhizome system is of paramount importance.

Limits to population growth are not well defined. At the present time, it would appear that environmental conditions (e.g., moisture, shade) at least partially restrict growth. One valuable source of information is from the monitoring program that was initiated on the Bighorn National Forest in 1999 (Fertig 2000b). As part of the baseline data gathered during this effort, the size and reproductive status of occurrences were reported. Stem density was variable, ranging from 27 to 50 stems per square meter in willow thicket/marsh habitats and from 10 to 48 stems per square meter in riparian Engelmann spruce forests. It was noted that large patches of seemingly suitable habitat were unoccupied between clusters and suboccurrences (see Distribution and abundance section). Whether this is due to a limitation on seed dispersal or because micro-habitat conditions were actually unsuitable for colonization is not known. The numbers of flowering and vegetative stems in two of the macroplots are presented in **Figure 8**. The number of flowering and vegetative stems were counted in 50 (macroplot A) or 60 (macroplot B) 0.4x1m plots (quadrats) using a stratified random procedure (Fertig 2000b). Plotting the data as a chart graphically demonstrates the very patchy nature of the distribution of stems and emphasizes the variation in flowering behavior between each cluster. The lines joining the points do not infer that the quads are contiguous, each being separated by a different distance; instead, they serve only to help match the flowering versus vegetative stems in the respective quads. Presenting the data as a scatter graph makes the patterns difficult to discern.

It appears that *Rubus arcticus* ssp. *acaulis* grows in patches, or rather as a subdivided population, but it is unknown if there is a balance of frequent local extirpations and colonizations within a colonized area or whether, once established, microsites are occupied for long periods of time. Studies such as those on the Bighorn National Forest (Fertig 2000b, Karow personal communication 2004) will elucidate many such issues. Studies on *R. arcticus* suggest that patches may be very long-lived, for example 160 years (Tammisola 1988; see Reproductive biology and autecology section). However, it is important to consider that patch size and persistence may depend on the habitat or even the microhabitat that is occupied. Therefore, conclusions from observations in one area must be conservatively applied elsewhere. In addition, a site that appears sub-optimal, for example with respect to the proportion of flowering stems or density of total stems, in one year may prove an excellent site in another year when the weather conditions are different. In any given area as well as at a larger scale, it is most likely that the different microsites occupied by *R. arcticus* ssp. *acaulis* act as a buffer against environmental stochasticity (Menges 1991).

Population viability analyses for *Rubus arcticus* ssp. *acaulis* have not been undertaken. Short-term analyses of population viability that emphasize demography rather than genetics may be particularly rewarding (Landes 1988, Menges 1991). Metapopulation analyses based on the proportion of occupied suitable microsites may be an effective method of understanding population viability of this species at the management level (Menges 1991). Studying the genetics of one or just a few populations may not represent the species in total and may lead to misconceptions (see Reproductive biology and autecology section). The genotypic diversity in clonal plant species was investigated, and genetic heterogeneity within populations was found to be highly variable (Ellstrand and Roose 1987). Multiclonal populations tended to be most common, but most clones were restricted to one or more populations, and widespread clones were exceptional (Ellstrand and Roose 1987).

In general, *Rubus* species are defined as stress-tolerant competitive individuals (Grime et al. 1988). However the current evidence, which indicates that *R. arcticus* ssp. *acaulis* is relatively uncompetitive and has high clonal reproduction and low sexual reproduction, suggests that it is a perennial species that is maintained in established populations and more accurately corresponds to the profile of a k-selected species (MacArthur and Wilson 1967) having a stress-tolerant life strategy (Grime et al. 1988). This life-strategy difference may also distinguish the genus *Cylactis* from *Rubus*.

Community ecology

Community and moisture requirements

Rubus arcticus ssp. *acaulis* grows in mountain meadows, boggy woods, marshes, fens, and willow communities (see Habitat section). The population size of *R. arcticus* ssp. *acaulis* is quite variable, from fewer than a dozen stems to several thousand stems (see Distribution and abundance section). Causes of the variation in population size are unknown, and it is

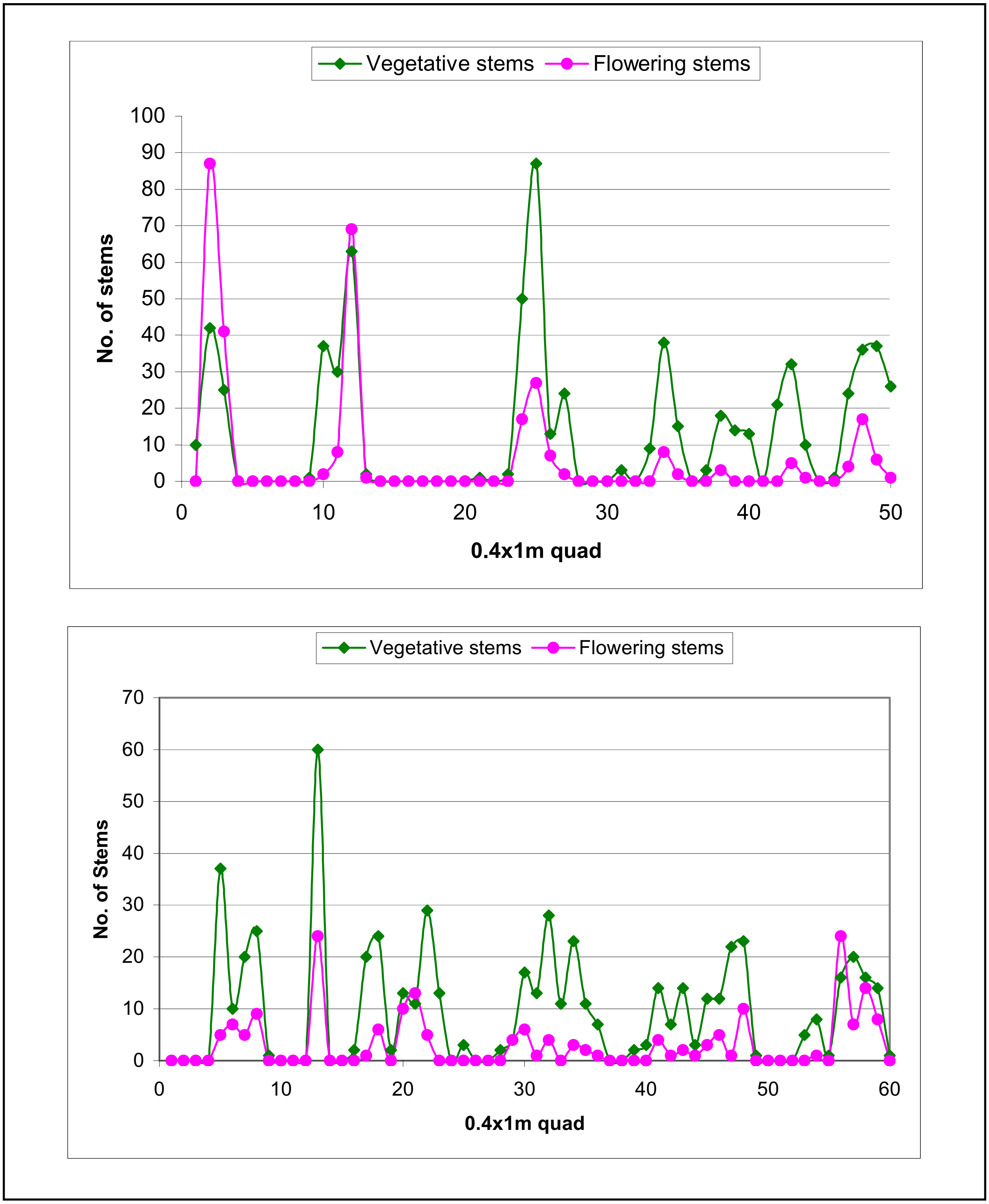


Figure 8. The variability in the number of *Rubus arcticus* ssp. *acaulis* flowering and vegetative stems per 0.4 m^2 quadrat (quad) within two plots in the Bighorn National Forest (from Fertig 2000b and information provided by G. Karow personal communication 2004). The quadrats were selected in macroplots using a stratified random procedure (Fertig 2000b).

likely that there are substantial variations in the number of stems and leaves between years due to temporally variable environmental conditions (see Demography section). *Rubus arcticus* ssp. *acaulis* typically grows in moist habitats in Region 2, and moisture is likely to be a critical element to its long-term survival. Yearly observations since 1999 suggest that water levels may be a significant factor in the year-to-year variation of the aboveground *R. arcticus* ssp. *acaulis* population in Sourdough Creek, Bighorn National Forest (**Table 1**). The information is anecdotal, but when the water level in the creek was high, as estimated by the paucity of sites where the creek could be crossed, the *R. arcticus* ssp. *acaulis* population appeared to be larger than when water levels were perceived to be lower (Karow personal communication 2004).

Competition with vascular plant species

The competitive ability of *Rubus arcticus* ssp. *acaulis* is not known with certainty. Several species of *Rubus* are themselves invasive. Photosynthetic characteristics were found to be more powerful than morphological characteristics in distinguishing between the invasive and noninvasive *Rubus* species (McDowell 2002). A high maximum photosynthetic rate and greater water use efficiency were identified as the most useful variables for distinguishing between the species, and they may be important factors contributing to the success of invasive species (McDowell 2002). Although it is not possible to deduce anything about the photosynthetic rate and water use efficiency of the taxon, its patchy and infrequent occurrence, as well as its small stature and apparent requirement for mesic conditions, suggests that it is not one of the more competitive *Rubus* species. Shading by herbaceous plants, shrubs, and trees is considered to be primarily responsible for the decline of some *R. arcticus* ssp. *arcticus* populations in northern Europe (Karp 1997).

Interaction with wildlife

Interactions between *Rubus arcticus* ssp. *acaulis* and the fauna of its associated community have not been documented in detail. Pollinators, probably bees, are needed for seed production (see Reproductive biology and autecology section). Mammals and birds eat the fruits and are likely to have a role in seed dispersal. Birds are particularly important in dispersing *R. arcticus* ssp. *arcticus* seed (Ryyänen 1973). Livestock, deer, elk, and moose use the areas in which *R. arcticus* ssp. *acaulis* grows in Region 2. Considering other *Rubus* species, palatability of the leaves and stems may be only moderately good (Dayton 1931, USDA Forest Service 1988). Observation also supports this supposition; there is little evidence of herbivory on *R. arcticus* ssp. *acaulis* plants in the Arapaho National Forest (Sumerlin personal communication 2004) or the Bighorn National Forest (Fertig 2000b). Typically, *R. arcticus* ssp. *acaulis* does not appear grazed or browsed when it is within a healthy riparian area where wildlife and livestock forage is diverse and plentiful (Sumerlin personal communication 2004). It is likely to be more susceptible to grazing in the absence of more palatable plants. *Rubus arcticus* ssp. *acaulis* may serve as a food source for certain arthropods. *Rubus arcticus* serves as a food plant for the larvae of many Lepidopteran arthropods, including the moth *Carsia sororiata*, which occurs widely from Alaska to New Hampshire and in Northern Europe.

Disease

There are several potential diseases of *Rubus arcticus* ssp. *acaulis*. Raspberry bushy dwarf virus (RBDV) is spread through pollen, whereby the maternal parent and the seeds become infected (Kokko et al. 1996). Initially this virus was reported to infect only *R. idaeus*, *R. occidentalis*, *R. ursinus*, and their hybrids, but Kokko et al. (1996) also determined that subspecies of *R. arcticus* are susceptible to the virus. The virus may cause yellow-colored foliage (most common), stunted growth, significant decrease in fruit size and yield, fruit abortion, and interruption of fruit development (Kokko et al. 1996). The presence of the virus did not always produce obvious symptoms in either *R. arcticus* ssp. *arcticus* or ssp. *stellatus* (Kokko et al. 1996). *Rubus arcticus* ssp. *arcticus* is susceptible to powdery mildew infection, at least under cultivated conditions (Tammisola 1988). Thrips are commonly observed on *R. arcticus* ssp. *arcticus* plants and principally damage the flower parts (Tammisola 1988).

Fire

Considering the role of fire on a rangewide basis, much of the habitat of *Rubus arcticus* ssp. *arcticus* is likely to have been exposed to fires having long return intervals. In years of average precipitation, wet habitats such as bogs and fens are usually too damp to burn. During drought years, however, bog surfaces can be dry enough to support fire (Flinn and Wein 1977, Dawson 1979, Sullivan 1994). In northern Minnesota peatlands, many conifer bogs burned in the same fires that consumed adjacent uplands (Heinselman 1973). In Quebec, the fire frequency for conifer bogs was estimated from stand age to be on the order of 100 to 200 years (Cogbill 1985). In addition, although fire return intervals are likely to be long, in some circumstances wildfires in adjacent conifer communities can affect fenland in western mountain environments (Ratchford et al. 2005). In the latter situation, fens appear to experience a patchy burn pattern, which is likely to contribute to a spatially diverse vegetation pattern.

The role of fire in the ecology of the *Rubus arcticus* ssp. *acaulis* occurrences in Region 2 is not known. The water-inundated or very moist habitats of *R. arcticus* ssp. *acaulis* in Region 2 are unlikely to experience fire directly except after long periods of drought when vegetation is susceptible to burning. Conifer forests upslope of occurrences may burn more frequently, possibly resulting in increased sediment accumulation downslope after the fires. The *R. arcticus* ssp. *acaulis* habitats that are drier, such as those on the Medicine Bow National Forest (see Habitat section), may be more susceptible to fire. There is the possibility that infrequent fires actually maintain these habitats, but this is speculative and more information on the potential response by *R. arcticus* ssp. *acaulis* is needed before using fire as a management tool in maintaining its habitat.

Rubus arcticus ssp. *acaulis* has been observed under a partly closed canopy (e.g., occurrences 4 and 6 in **Table 4**), and therefore plants must be able to tolerate a certain amount of shade. However, shade may have a profound influence on flowering and therefore reproductive success (see Reproductive biology and autecology section). It is possible that the ecology of the two subspecies (ssp. *acaulis* and ssp. *arcticus*) differs with respect to shading and the importance of fire to the life cycle, but the following observations on subspecies *arcticus* may be worthy of consideration.

Rubus species typically are adapted to cycles of fire and other disturbances (Oliver and Larson 1996). They tend to grow during the first few years after fire before the taller-growing trees shade them out. After the raspberries die, the seeds are reported to remain dormant in the soil until the next fire or disturbance event prompts them to germinate. *Rubus arcticus* ssp. *arcticus* does not tolerate heavy shade and increases in response to woodland clearing and fire (Ryynänen 1973). Apparently, seeds also germinate well in burned fields (Tammisola 1988). In northern Europe, *R. arcticus* ssp. *arcticus* has been observed to "suddenly appear" in areas where trees have been cleared by fire, and it was speculated that this was due to the taxon being already there and having "rested as rhizomes" for several years (Saastamoinen 1930, Ervi et al. 1955 in Tammisola 1988). Seed germination may also be responsible for the (re)colonization. It is believed that substantial canopy closure eventually leads to population extirpation and finally extinction (Karp 1997). Even though reducing canopy cover is currently believed to be most important, *R. arcticus* ssp. *arcticus* may respond to other consequences of fire. Some other effects of fire include removing litter, eliminating or reducing competition from other species, and changing the soil nutrient and microbial environment (Oliver and Larson 1996, Whelan 1997). Curtis and Partch (1950) found that clipping *Andropogon* (bluestem) swards produced increases in density and height of flowering stems virtually equivalent to those occurring after burning. Granted *Andropogon* is a grass, but the impact of litter on *R. arcticus* ssp. *arcticus* has not been evaluated and needs to be considered. Although a consequence of fire is an increase in nutrients in the soil that may benefit the plant, nitrogen can be also be lost by volatilization.

Summary

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984), but they may also be applied to describe the condition of plant species. Those components that directly affect *Rubus arcticus* ssp. *acaulis* make up the centrum, and the indirectly acting components constitute the web (**Figure 9**, **Figure 10**). Unfortunately, as mentioned previously, much of the information to make a comprehensive envirogram for this taxon is unavailable. The envirograms in **Figure 9** and **Figure 10** are constructed to outline some of the major components known to impact the species directly and include some more speculative factors that can be tested in the field by observation or by management manipulation. Dotted boxes indicate resources or malentities that are either likely but not proven, or are of a regional nature. At the micro-site level, some interactions can be deduced, such as locally colonizing less shaded areas, but the lack of direct studies on this subspecies leads to stretching the significance of observations and forming opinions from inference rather than fact. Inferences must be tested and are dangerous to use in predicting responses to management decisions. Resources (**Figure 9**) have been listed as adequate moisture; suitable organic soils; animals, especially birds for seed dispersal; and arthropods, especially bees, for pollination.

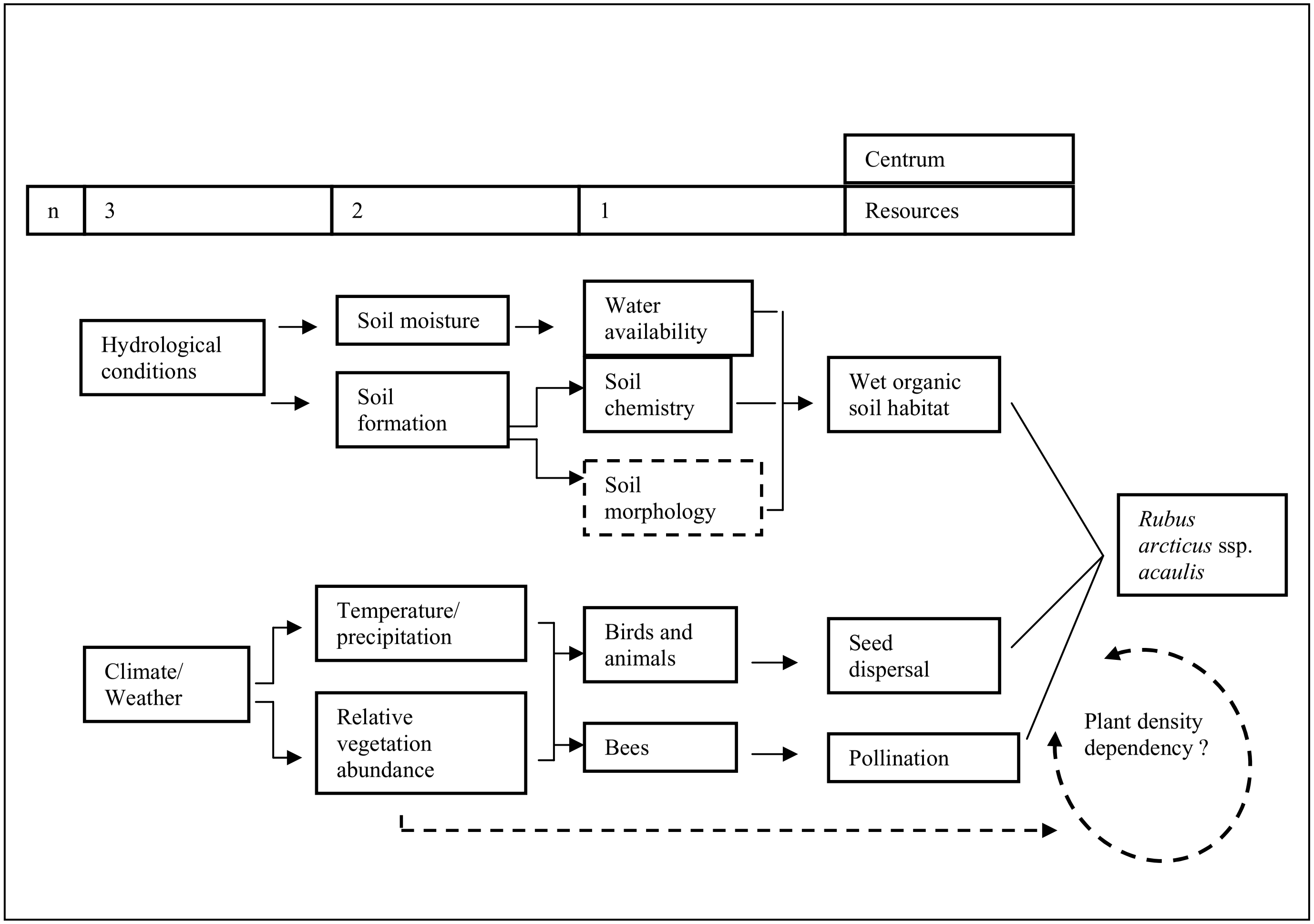


Figure 9. Envirogram outlining the resources of *Rubus arcticus* ssp. *acaulis*. Dotted boxes indicate resources that are not proven. Those components that directly impact *R. arcticus* ssp. *acaulis* make up the centrum, and the indirectly acting components constitute the web.

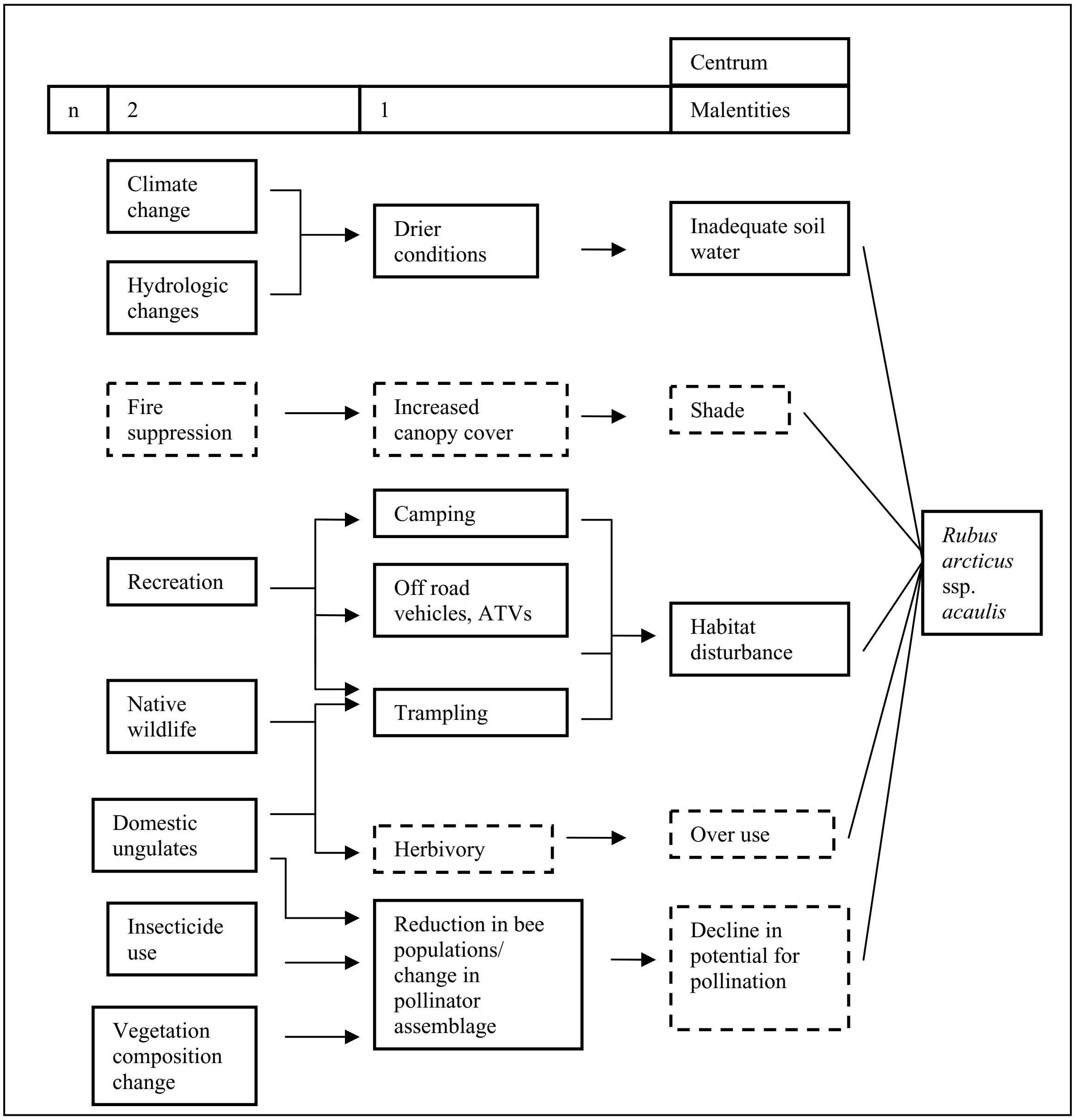


Figure 10. Envirogram outlining the malentities to *Rubus arcticus* ssp. *acaulis*. Dotted boxes indicate malentities that are not proven. Those components that directly impact *R. arcticus* ssp. *acaulis* make up the centrum, and the indirectly acting components constitute the web.

CONSERVATION

Threats

The most likely immediate and potential threat to *Rubus arcticus* ssp. *acaulis* occurrences is habitat loss. Anthropogenic causes of habitat loss include human recreation activities, livestock grazing, and extraction of natural resources (e.g., timber and peat). Logging, recreation, and water impoundments have been reported as the main threats to *R. arcticus* ssp. *acaulis* populations in Wyoming (Fertig 2000a). Road construction and improvements may pose a threat to some occurrences, particularly those in Region 2. Water availability may be one of the most critical environmental variables for *R. arcticus* ssp. *acaulis*, and any circumstance that leads to drier habitat conditions may pose a substantial threat. Hydrology issues are linked to other threats and are discussed in several sections below. Invasive, non-native plant species may threaten some occurrences by directly competing with *R. arcticus* ssp. *acaulis* for resources and by contributing to habitat degradation. Wildlife browsing and trampling may pose a threat, especially when combined with livestock grazing pressure. The consequences of fire and fire suppression are unknown but may affect the availability of suitable habitat. Recreational and commercial berry picking appears to be a substantial threat to *R. arcticus* ssp. *acaulis* occurrences that are within easy reach of urban centers in northern regions, but collection of *R. arcticus* ssp. *acaulis* fruit is not considered a threat in Region 2. Like all species, *R. arcticus* ssp. *acaulis* occurrences are vulnerable to environmental stochasticity and natural catastrophes. Warmer temperatures and/or drier conditions associated with global climate change are potential threats. Atmospheric nitrogen deposition may threaten some occurrences, like those in the Front Range in Colorado. The role of cross-pollination in *R. arcticus* ssp. *acaulis* population maintenance is not documented, but the species may be vulnerable over the long term to declines in pollinator populations. Demographic and genetic stochasticities are also potential threats, and it is likely that small and disjunct *R. arcticus* ssp. *acaulis* occurrences, such as those in Wyoming and Colorado, are the most vulnerable. Each threat or potential threat and its relevance to populations on land managed by the USFS in Region 2 is discussed in the following paragraphs.

The role of disturbance in the life history of *Rubus arcticus* ssp. *acaulis* is unknown. It has been hypothesized that *R. arcticus* ssp. *arcticus* benefits from an intermediate disturbance regime (Tammisola 1988). However, disturbance by anthropogenic activities (e.g., trampling, off-road vehicle traffic) or its consequences (e.g., increased soil erosion, cumulative soil compaction due to repeated foot traffic on a trail) have different ecological consequences from those of natural disturbance, such as cryoturbation and fire. Therefore, the impacts and consequences of a specific disturbance regime must be clearly recognized, and management decisions need to reflect this comprehension.

Recreation

Recreational activities may threaten some *Rubus arcticus* ssp. *acaulis* populations in Region 2. Foot traffic may be a significant threat in some areas. Known populations in Colorado (**Table 1**) are in areas where there is considerable use by hikers, but boggy conditions may deter heavy use of the habitat. More use, however, may occur in drier microsites or during drier seasons. A sub-occurrence upstream from a bridge at occurrence 4 (**Table 1**) on the Arapaho National Forest could be threatened by a ford that bypasses the bridge (Colorado Natural Heritage Program 2004).

At least one population in Yellowstone National Park is located along a pack trail and may be impacted by trampling (Fertig 2000b). Bridge construction affected part of an occurrence in Yellowstone National Park, and *Rubus arcticus* ssp. *acaulis* has been extirpated from the immediate area (Whipple personal communication 2006). Loss of plants appears to be linked to the loss or disturbance of the peat substrate. Prior to construction, the area was peatland, but although the area remains a wetland, it can no longer be categorized as a peatland (Whipple personal communication 2006). The consequence of this loss is that potential impacts from development projects are being more stringently reviewed (Whipple personal communication 2006). A proposed reroute of a trail in 2006 has the potential to affect another of the suboccurrences in Yellowstone National Park, but surveys will be made prior to the project to ensure that *R. arcticus* ssp. *acaulis* plants are avoided (Whipple personal communication 2006). Development of new recreation facilities in conjunction with the Tie Hack Dam and Recreation Area could lead to some habitat loss and degradation on the Bighorn National Forest (Fertig 2000b).

Livestock and wildlife

The effects of historic livestock grazing cannot be estimated, but present-day herbivory by livestock and wildlife is unlikely to be a significant threat (Fertig 2000b, Sumerlin personal communication 2004). *Rubus arcticus* ssp. *acaulis* does not appear to be significantly grazed or browsed, at least when it is within a healthy riparian area where wildlife and livestock forage is diverse and plentiful (Sumerlin personal communication 2004). On the Arapaho National Forest, a suboccurrence near a bridge persists in an area that used to be grazed by domestic cattle in addition to the wildlife (i.e., deer, elk, moose) that still use the area (Sumerlin personal communication 2004). However, it is not known whether grazing influences fruit production (Fertig 2000b). Forbs tend to produce fewer inflorescences when defoliated just before or during flowering (Blaisdell and Pechanec 1949, Mueggler 1967, Edwards 1985).

Although *Rubus arcticus* ssp. *acaulis* appears to tolerate the current levels of grazing pressure, the consequences of trampling by livestock and wild ungulates may be of potential concern. In the Bighorn National Forest in 1995, some trampling of wetland habitats was observed (Fertig 2000b). There is evidence that cattle livestock congregate near the Sourdough Creek population, and moose browse on the willows in the area (Karow personal communication 2004). However, the *R. arcticus* ssp. *acaulis* population along Sourdough Creek persists and does not appear to be severely impacted by grazing activities (Fertig 2000b). The potential for trampling also exists at occurrences on the Arapaho National Forest, but suboccurrences have been seen to persist in the presence of livestock, extensive moose use, and continual deer and elk presence (Sumerlin personal communication 2004). Of course, persistence of a taxon per se is not proof that the taxon is unaffected by an activity. A decrease in reproductive output, a shift from sexual reproduction to vegetative reproduction, and/or a change in the belowground population size are all potential reactions that are not considered in a simple explanation of persistence. In addition to direct impacts on herbage, livestock grazing can lead to the drying out of wet meadows through alteration of the hydrology in the area (Murray 1997). Landscape hydrology can be altered by trails created from livestock movement patterns, which alter surface water flows (Fredrickson 2004). Livestock grazing can also compact soil and change vegetation composition and structure, which also can lead to drying of meadows (Nicholoff 2003). Livestock also contribute to the spread of invasive weeds (Sheley and Petroff 1999). Livestock carry seed on their hair and feet and can disperse seed after ingestion. Habitat modification rather than damage from the direct impacts of herbivory appears to be the greatest cause for concern for *R. arcticus* ssp. *acaulis*.

Resource extraction – timber

Logging and tree cutting are common throughout the range of *Rubus arcticus* ssp. *acaulis*. Logging or tree cutting activities can be expected to open previously closed canopies and may provide more open habitat. However, these activities will also contribute to compaction and soil disturbance and may increase available habitat to invasive plant species. Such consequences might be directly detrimental to *R. arcticus* ssp. *acaulis* plants. Tie hacking, a process formerly used to produce railroad ties, provides an example of the diverse and long-lasting effects of tree cutting. Tie hacking was particularly common in the late 1920's and early 1930's in the Sourdough Creek Area in the Bighorn National Forest, Region 2 (Karow personal communication 2004). Each tie had to be 8 ft. long, and at least 7, but no more than 7.75, inches in depth. Historically, the Sourdough Creek drainage on the Bighorn National Forest in Region 2 may have been affected by changes to in-stream flow as a result of tie hacking activity. As part of this activity, a splash dam was constructed approximately 0.5 mile upstream from the current *R. arcticus* ssp. *acaulis* population in Sourdough Creek (Karow personal communication 2004). Channel erosion, incision, and scouring increased as a result of increased peak flows associated with splash dam releases (Napolitano 1998). There is evidence of old beaver dams in the drainage, and their mitigating effects on the potential for scouring have not been assessed. The consequences of downstream water impoundment were also of concern in this area, and the construction of the Tie Hack Dam in 1997 was once considered an important threat to the Sourdough Creek *R. arcticus* ssp. *acaulis* population (Fertig 2000b). However, the Tie Hack Dam is more than one mile downstream from the population, and the reservoir has inundated little, if any, *R. arcticus* ssp. *acaulis* habitat (Fertig 2000b, Karow personal communication 2004).

Resource extraction – peat mining

Historically, peat mining is likely to have affected some *Rubus arcticus* ssp. *acaulis* populations throughout its range, and peatland exploitation may remain a threat in many parts of its range in the future (Chapman et al. 2003). The USFS considers peat a saleable mineral, and three sites in Colorado are currently being mined (Baer personal communication 2006). Although peat mining has not been as developed in Colorado as it has in many other parts of the world, evidence of extensive past activities exists (Cooper and MacDonald 2000). One example is in the Warren Lakes area on the White River National Forest in Colorado. Several ditches, ranging from 2 to over 10 ft. wide, were machine-dug many decades ago to extract peat from this area (Cardamone personal communication 2002). Such activity influences soil structure and composition, microbial and non-vascular and vascular plant species composition, as well as site hydrology. Peat mining was also carried out in the 1980's on private land in a northern portion of Geneva Park, Colorado, and this apparently led to the extirpation of a patch of *Ptilagrostis porteri* (Porter feathergrass) (Center for Native Ecosystems et al. 2002). There is the potential that peat extraction has affected some *R. arcticus* ssp. *acaulis* populations in the past, but there are no documented impacts. In the future, commercial peat extraction may be limited, especially on federally managed land in Colorado and Wyoming, because peatlands may become protected as a "Category 1 Resource" (U.S. Fish and Wildlife Service 1981, 1993).

Road construction and improvement

Construction activities and the consequences of road improvements are potential threats to occurrences

1 and 2 (**Table 1**) at Geneva Park on the Pike National Forest in Colorado (U.S. Department of Transportation 2003). The environmental impact statement (EIS) prepared by the Federal Highway Administration (FHWA) for the project indicated that some areas in "Geneva Park will be temporarily fenced to protect rare plant areas" and "measures to minimize harm for wetland and riparian impacts" would be taken during construction (U.S. Department of Transportation 2003). *Rubus arcticus* ssp. *acaulis* (referred to in the EIS as Northern blackberry) was considered by name, and the FHWA planned to identify construction boundaries using temporary fencing to protect specific occurrences of the species. In addition, special provisions were planned to be included in the construction contract regarding the area, including penalties for transgression of the construction boundary (U.S. Department of Transportation 2003).

Invasive plant species

Invasive weed species may present a significant threat because *Rubus arcticus* ssp. *acaulis* is not likely to be a particularly competitive species (see Community ecology section). This theory may be supported by the results of an experiment on vertebrate-predator exclusion effects on vegetation in Finland. The experiment was designed to determine the effects of protecting voles from their predators on the vegetative cover of various plant taxa (Norrdahl et al. 2002). Plots were unfenced (controls) or fenced to exclude larger animals and thus increase the vole population. The consequences of increasing vole (herbivore) density on *R. arcticus* were unclear and no correlations could be generated. However, the results showed an interesting correlation between weed species and *R. arcticus*. Over the four year study, although much of the vegetative cover including the competitive species Canada thistle (*Cirsium arvense*) and fireweed (*Epilobium angustifolium*), increased two-fold or more both in both the fenced and unfenced plots, the cover by *R. arcticus* declined by more than 10-fold. One interpretation of these results is that the weedy species were outcompeting *R. arcticus*. Both *C. arvense* and *E. angustifolium* (synonym *Chamaenerion angustifolium*) are found in Region 2. *Cirsium arvense* is a non-native species and is listed as a noxious weed in Colorado and Wyoming (USDA NRCS 2004, Wyoming Weed and Pest Council Undated). *Epilobium angustifolium* is a native, early successional species but has been included in some weed-identification texts since it possesses some of the characteristics of an invasive species and tends to increase in some regions in response to disturbances (Taylor 1990, Whitson et al. 1991, Aiken et al. 2003).

Fire and fire suppression

The role of fire in *Rubus arcticus* ssp. *acaulis* ecology is not known. Water-inundated habitats are only likely to experience fire during drought years (see Community ecology section). Fire apparently plays some role in habitat maintenance of *R. arcticus* ssp. *arcticus* (see Community ecology section). However, it may be particularly detrimental to isolated *R. arcticus* ssp. *acaulis* occurrences, such as those in Region 2, that have no or low sexual reproduction since fire may damage the underground rhizome network and seed would not be available in the seed bank for recolonization. Conversely, it is difficult to speculate on the consequences of long-term fire suppression on *R. arcticus* ssp. *acaulis* in Region 2 because of the paucity of historic records. Periodic fire may open up otherwise overly shaded or overgrown habitat for *R. arcticus* ssp. *acaulis* much as it does for subspecies *arcticus* (Tammisola 1988). There were large fires upstream of the population on the Bighorn National Forest in the late 1890's and 1940's, but it is not known whether the population was directly subjected to fire (Karow personal communication 2004). An indirect effect of the fires may have been to increase sediment deposition downslope or downstream of an occurrence. The impact of sediment burying *R. arcticus* ssp. *acaulis* plants likely depends on the depth and composition of the sediment.

Harvest and collection

Berry picking is a substantial threat to many *Rubus arcticus* ssp. *acaulis* populations that are in areas within easy reach of urban centers in northern parts of its range where wild berry harvesting is popular. However, collection of *R. arcticus* ssp. *acaulis* fruit is not considered a threat in Region 2 since the local culture has not embraced wild raspberry picking. In addition, fruit production is apparently very low and variable in Region 2 and unlikely to draw human attention. Similarly, collection of plants in Region 2 for the horticultural trade is not perceived to be a threat.

Environmental stochasticity and natural catastrophe

Many elements of environmental stochasticity pose threats to the existence of population or species. Environmental stochasticity includes variation in the physical environment and biological interactions, such as with predators, parasites, disease, and interspecies competition. Natural catastrophes, such as floods and avalanches, represent extreme elements of environmental stochasticity. Most critical among environmental variables for *Rubus arcticus* ssp. *acaulis* may be the availability of water. The characteristics of the habitats typically colonized by *R. arcticus* ssp. *acaulis* suggest that it requires the perpetuation of a certain hydrological regime. Therefore, the taxon appears to be vulnerable to any activity that will cause its habitat to become drier. In some situations, logging, livestock grazing, and water development projects may result in reduced moisture levels in *R. arcticus* ssp. *acaulis* habitat (Fertig 2000b, USDA Forest Service 2002).

Of the natural catastrophes that could occur, prolonged drought is likely the most significant threat to this taxon in Region 2. High temperatures in conjunction with drought may be especially damaging. A significant threat to most high-elevation, sub-arctic and arctic taxa, including *Rubus arcticus* ssp. *acaulis*, is global climate change. Warming could affect alpine areas, causing tree lines to rise by roughly 350 feet for every degree Fahrenheit of warming (U.S. Environmental Protection Agency 1997). Mountain ecosystems such as those found in the Rocky Mountains could shift upslope, reducing habitat for many sub-alpine and alpine tundra species and increasing the likelihood that alien aggressive species will invade higher elevations (U.S. Environmental Protection Agency 1997). In the last one hundred years, the average temperature in Fort Collins, Colorado, has increased 4.1 °F, and precipitation has decreased by up to 20 percent in many parts of the state. Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), by the year 2100 temperatures in Colorado could increase by 3 to 4 °F in spring and fall (U.S. Environmental Protection Agency 1997). Within the same time period, the temperatures in Colorado could increase by 5 to 6 °F, and perhaps as much as 12 °F, in summer and winter (U.S. Environmental Protection Agency 1997). Similar perturbations are predicted for Wyoming using the same HadCM2 model (U.S. Environmental Protection Agency 1998).

Atmospheric deposition of nitrogen oxides and ammonium is increasing throughout the world. The western United States has been less affected than the eastern, but there are relative hotspots of elevated wet nitrogen (acid rain) deposition in southern California and along the Colorado Front Range, which includes parts of Region 2 (Baron 2001). Wet nitrogen deposition occurring in the high mountain areas of the Colorado Front Range is high enough to cause chemical and ecological changes (Baron et al. 2000, Baron 2001, Rueth and Baron 2002). Experiments have indicated that nitrogen additions in alpine tundra can influence the species composition of the community (Theodose and Bowman 1997). An increase in nitrogen may affect vegetation composition less in nutrient-rich sites than in nutrient-poor sites (Theodose and Bowman 1997). The consequence of increased nitrogen deposition on *Rubus arcticus* ssp. *acaulis* is not known. Berry production of *R. arcticus* ssp. *arcticus* is stimulated by high levels of complete fertilizer but only in the absence of other vegetation (Ryynänen 1973). In plots with fertilizer, *R. arcticus* ssp. *arcticus* was "choked" by other vegetation (Ryynänen 1973). The fertilizer (5% N: 12% P2O5: 15% K2O) was applied at rates of 0, 5, and 10 kg per arce (Ryynänen 1973). Levels of nitrogen in the fertilizer mix used in the experiments reported by Ryynänen (1973) appear to be relatively low, and other elements may have had a considerable influence on plant responses. The response of *R. arcticus* ssp. *acaulis* to wet nitrogen deposition is likely to be complex and subject to a combination of undetermined variables.

Loss of appropriate pollinators may be an additional threat. If *Rubus arcticus* ssp. *acaulis* is an obligate outcrosser, appropriate pollinators are critical. Reasons for pollinator declines include the use of pesticides, habitat alteration, pathogen epidemics, and insularization of habitat (Bond 1995). Grazing may indirectly affect pollinator activity. Sugden (1985) reported that sheep grazing endangers bee pollinators by destroying potential and existing nest sites and removing food resources. In this case, the grazing animals need not be directly within suitable *R. arcticus* ssp. *acaulis* habitat, only in the habitat of their pollinators. The possibility that specialist bee species are involved in pollination (Tammisola 1988; see Reproductive biology and autecology section) only increases this taxon's vulnerability to changes in arthropod assemblage and abundance.

One potential advantage of the clonal growth habit of *Rubus arcticus* ssp. *acaulis* is that its sensitivity to environmental stochasticity may be buffered (Menges 1991). A four-year field study of *Yucca glauca* (soapweed yucca) an obligate outcrosser, showed that asexual reproduction contributes to population stability by reducing impacts of variable pollinator availability and the need for annual recruitment (Kingsolver 1986).

Demographic stochasticity

Few comments can be made on the influence of demographic stochasticity on individual populations because there is no information on the survival probability and behavior of individuals at any given life-stage or age (see Demography section). Demographic stochasticity refers to chance events independent of the environment that may affect the reproductive success and survival of individuals, which in very small populations have an important influence on the survival of the whole population (Kendall and Fox 2002). Demographic stochasticity, for example variation in fecundity, may be significant where there are few individuals, perhaps fewer than 50, in a population (Pollard 1966, Keiding 1975). The situation with a clonally propagating species is complex because a subterranean connection may actually join many apparent individuals, and therefore an occurrence may be more vulnerable than initially supposed. Ramet and genet dynamics can differ greatly, and the minimum viable population size can vary widely according to the different proportions of genets or ramets making up the population (Damman and Cain 1998, Erikkson 1994, Menges 2000). More research is required to determine the importance of demographic stochasticity to population sustainability. Demographic stochasticity is typically not considered as great a threat to population viability as systematic factors such as continuing habitat loss or elements of environmental stochasticity (Menges 2000).

Genetic stochasticity

Genetic stochasticity is associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations. Genetic stochasticity is particularly of concern in small populations of individuals (Menges 1991). The genetic size of any population of *Rubus arcticus* ssp. *acaulis* cannot be estimated without detailed analyses because of its extensive clonal propagation. The potential for low genetic diversity within occurrences and relatively high vulnerability to genetic stochasticity is likely to be relevant to the *R. arcticus* ssp. *acaulis* plants on USFS land in Region 2 because of their isolation and low fruit production.

Hybridization can cause a loss of genetic integrity (see Reproductive biology and autecology section). The current evidence suggests that this is an unlikely threat to *Rubus arcticus* ssp. *acaulis* in Region 2. When considering potential hybrids in the field, it needs to be remembered that *Rubus* is a phenotypically plastic genus and that one may be looking at ecotypes rather than evidence of hybridization. Currently, commercial cultivation of *Rubus arcticus* appears to be limited to Scandinavia (Finn 1999). The potential for hybridization with introduced *R. arcticus* cultivars within Region 2 appears to be very low unless they are used for revegetation projects.

Threats summary

In general, threats to *Rubus arcticus* ssp. *acaulis*, including those concerned with global climate change, are likely largely dependent upon their extent and their intensity. At the current time, malentities or threats tend to be of regional, rather than universal, importance and are indicated as such in the envirogram in **Figure 10** by dotted lines. Potential malentities include invasive plant species, which will be direct competitors for resources such as water, nutrients, and light; and sources of habitat disturbance, which includes hikers, campers, and large ungulates. Recreational activities, livestock grazing, and wildlife browsing do not appear to be of critical concern at the current levels in Region 2. However, the emphasis is on current levels. Even if the intensity of a threat remains the same, an increase in its area of impact will eventually have negative consequences on the species. Trampling may be directly deleterious, but such disturbance also has indirect impacts, such as increasing soil erosion and modifying hydrological regimes; these effects need to be assessed on a case-by-case basis (Murray 1997). Fire might be important in maintaining suitable habitat. Therefore, fire suppression has been included, but in a dotted box to indicate its speculative nature. The extent and duration of malentities are important factors and need to be considered in any management decisions.

Conservation Status of Rubus arcticus ssp. acaulis in Region 2

There is no evidence to support or refute that the distribution or abundance of *Rubus arcticus* ssp. *acaulis* has changed either within Region 2 or within its total range within the last century. Although in parts of its range *R. arcticus* ssp. *acaulis* is fairly frequent, it appears to be very infrequent in others, particularly in Colorado, Wyoming, Michigan, and Washington. Because it is such a rare taxon in Region 2, the Regional Forester designates *R. arcticus* ssp. *acaulis* a sensitive species. When a taxon is designated sensitive, a biological evaluation must be made to determine the potential impact to the viability of populations within areas affected by any USFS projects. While the designation as a sensitive species does not prohibit loss of individual plants to the projects, it does require that the project be evaluated and that USFS actions not contribute to a loss of population viability on the planning area (USDA Forest Service 2003a). If a taxon is particularly abundant in a certain area and a portion of the population may be lost, the project may still proceed because it may be concluded that the loss would not affect the viability of the population in total. For example, because of its sensitive species status, plans were made to minimize impacts to *R. arcticus* ssp. *acaulis* occurrences on the Pike National Forest during a road improvement project (see Threats section).

Maintaining population data on sensitive species is useful not only for determining the status of the individual species, but also for evaluating the overall health of communities in the national forests. The Bighorn National Forest has monitored the population of *Rubus arcticus* ssp. *acaulis* at Sourdough Creek since 1999 (Karow personal communication 2004). Although not sufficiently widespread to use as a forest-wide Management Indicator Species (MIS), this mesophytic perennial may prove to be an indicator of hydrologic changes in the local ecosystem.

Management of Rubus arcticus ssp. acaulis in Region 2

Implications and potential conservation elements

At the present time, most of the known *Rubus arcticus* ssp. *acaulis* occurrences within Colorado and Wyoming are on land managed by the USFS Region 2 (**Table 1**). Of five occurrences that have been (re)located in the last decade in Colorado and Wyoming, four are on National Forest System lands in Region 2. All four occurrences appear to have large numbers of aerial stems, but the numbers of individuals at each occurrence are not known. Each of these occurrences is likely to be genetically isolated from other occurrences (see Distribution and abundance section and **Table 1**). For conservation purposes, the total number of occurrences is as important as the total numbers of individuals. One large occurrence is more vulnerable to one localized environmental (e.g., flooding) or biological (e.g., fungal infection) event than are several disjunct, small occurrences.

The population currently known in the Bighorn National Forest is in a grazing allotment, and the taxon is distributed through areas that are managed principally for either scenery (Management Unit code 4.2) or where forest vegetation (Management Unit code 5.11) or rangeland vegetation (Management Unit code 5.12) is emphasized (Bornong personal communication 2004, USDA Forest Service 2004-2008). The population on the Arapaho National Forest is not currently in an active grazing allotment, and the area is used primarily for recreation. In the Pike National Forest, *Rubus arcticus* ssp. *acaulis* grows in an area primarily managed for recreation (Management area 2B; USDA Forest Service 1984).

The persistence of *Rubus arcticus* ssp. *acaulis* populations apparently depends on relatively long-lived mature individuals. Therefore, management practices that increase either the frequency or intensity of natural perturbations, or that provide additional stresses may significantly negatively affect population viability. The status of *R. arcticus* ssp. *acaulis* seeds in the seed bank is important but unknown. If seeds are stored in the soil seed bank, then there is the potential for re-establishment after fire or disturbance. If seeds are absent, it is unknown what the consequences of fire or disturbance might be. Rhizomes may be able to resprout after a low intensity fire or moderate disturbance of the soil surface, but this is unlikely if the soil is deeply disturbed or if the fire is of high intensity.

Some *Rubus arcticus* ssp. *acaulis* occurrences in wetlands may have received protection from development by the Section 404 regulatory program of the Clean Water Act (Comer et al. 2005). This program requires that a permit be obtained from the USACE before performing any activity that moves even a small amount of earth into the "waters of the United States" (U.S. Environmental Protection Agency 1977). Prior to 2001, a broad regulatory definition of "waters of the United States" was used, and this afforded federal protection for almost all of the nation's wetlands, including "isolated" wetlands and other intermittent waters (Legal Information Institute Undated). However, in 2001, the Supreme Court made the decision that Congress had not granted the US Army Corps of Engineers jurisdictional Clean Water Act authority over "isolated" wetlands (Supreme Court of the United States 2001). A much narrower definition of what constitutes "waters of the United States" has been proposed, which removes from Clean Water Act protection "isolated" wetlands as well as non-navigable tributaries of traditionally navigable waters, intermittent and ephemeral streams, and waters that pass through human-made conveyances" (Legal Information Institute Undated). Therefore, protection of many wetlands, and the species therein, will be subject only to individual state laws and local ordinances. It is possible that the change in the interpretation of these provisions of the Clean Water Act may affect *R. arcticus* ssp. *acaulis* occurrences since the extent of wetlands determined to be isolated is extensive (Tiner et al. 2002).

Those *Rubus arcticus* ssp. *acaulis* occurrences associated with substantial peat deposits in the United States, especially in the Rocky Mountains, may be protected in the future since peatlands have been placed within “Resource Category 1” of the U.S. Fish and Wildlife Service wetland mitigation policy (U.S. Fish and Wildlife Service 1981). The criteria for habitat to be designated “Resource Category 1” is that the “habitat to be impacted is of high value for evaluation species and is unique and irreplaceable on a national basis or in the ecoregion section” (U.S. Fish and Wildlife Service 1993). Furthermore, “the mitigation goal for habitat in Resource Category 1 is no loss of existing habitat value” (U.S. Fish and Wildlife Service 1993). Peatland formation is extremely slow in the Rocky Mountains, representing a unique and essentially irreplaceable resource (Cooper and MacDonald 2000).

The genetic variation in *Rubus arcticus* ssp. *acaulis* populations in Region 2 is also unknown, and there are no estimates of the taxon’s genetic vulnerability. Small populations are often considered genetically depauperate because of changes in gene frequencies due to founder effects (Menges 1991; see Reproductive biology and autecology section). Although not invariably, locally endemic species tend to exhibit reduced levels of polymorphism (Karron 1991, Gitzendanner and Soltis 2000). If the plants in Region 2 exhibit low levels of sexual reproduction, the contribution of founder effects may be considerable in these disjunct and isolated populations. However, this situation would be in contrast to that found for *R. arcticus* in Finland (Lindqvist-Kreuze et al. 2003). The levels of genotypic and genetic variation were estimated in six natural populations of *R. arcticus* in Finland (Lindqvist-Kreuze et al. 2003). Three DNA (deoxyribonucleic acid) primer combinations were used to generate amplified fragment length polymorphisms (AFLPs). The genotypic variation was measured several ways and was found to be high within all populations. The high levels of genetic diversity indicated that sexual reproduction played a significant role in maintaining these populations (Lindqvist-Kreuze et al. 2003). Therefore, direct site-specific studies on *R. arcticus* ssp. *acaulis* need to be made in order to determine its genetic vulnerability. It may be noted that DNA fingerprinting techniques are likely to be more successful than isoenzyme analysis when determining genetic variation within *Rubus* populations (Nybom and Schall 1990; see Reproductive biology and autecology section).

Even though the genetic variation within a *Rubus arcticus* ssp. *acaulis* population is impossible to estimate and may be very small, the variation in habitat colonized by *R. arcticus* ssp. *acaulis* suggests that considerable genetic differences may exist between populations. Ecotypes may have evolved that are physiologically different from one another. It is also likely that the most geographically separated populations will have the greatest genetic divergence. Therefore, significant loss of genetic diversity will likely result if populations at the edge of the range or in obviously disjunct localities, as are those in Colorado and Wyoming in Region 2, are lost. The *R. arcticus* study by Lindqvist-Kreuze et al. (2003) supports such speculation. They found that although the hierarchical analysis of molecular variance (AMOVA) suggested a high level of population differentiation, a low level of interpopulation gene flow was indicated.

Management plans have not specifically addressed this species. There tends to be little direct information on which to base predictions about its response to specific disturbance types or levels. Although information on *Rubus arcticus* ssp. *arcticus* is useful and appears relevant, it cannot substitute for observations on *R. arcticus* ssp. *acaulis*. The persistence of *R. arcticus* ssp. *acaulis* in areas with high rates of grazing by livestock and wildlife suggests that it may be tolerant of such activity. However, there is no information as to its abundance prior to the current conditions. Neither have careful observations been made as to the effects of current conditions on its physiology and reproductive biology (see Reproductive biology and autecology and Community ecology sections). Appropriate pollinators may be critical to seed production, and therefore any activity that affects either pollinator activity or abundance may affect the reproductive success of *R. arcticus* ssp. *acaulis*. Anthropogenic activities (e.g., livestock grazing, hiking) and global warming may exacerbate the potential colonization of *R. arcticus* ssp. *acaulis* habitats by invasive, competitive plant species. This threat from invasive species needs to be given attention in management planning.

Tools and practices

Documented inventory and monitoring activities are important to understanding the status of any taxon. Most of the occurrence information for *Rubus arcticus* ssp. *acaulis* is derived from herbarium specimens or from relatively casual observations by botanists and does not provide quantitative information on the abundance or spatial extent of the populations.

Historically, there is little information on the population structure and persistence of either individuals or populations. A notable exception is that the Bighorn National Forest has implemented yearly monitoring on six plots since 1999.

Species inventory

An intensive inventory for *Rubus arcticus* ssp. *acaulis* was made on the Bighorn National Forest during the 1990's (Fertig 2000b). The procedures used can be reviewed during the design phase of other inventories (Fertig 2000b, USDA Forest Service FY 2004-2008). The current "Field survey form for endangered, threatened or sensitive plant species" used by the Bighorn National Forest (USDA Forest Service FY 2004-2008) and the data collection forms used by state natural resources programs all request information that is appropriate for inventory purposes (e.g., see Colorado Natural Heritage Program and Wyoming Natural Diversity Database Internet sites in the **References** section for examples of data collection forms). The numbers of stems, the area they actually occupy, and the relative extent of apparently suitable habitat are important data for occurrence comparison. However, it is important to note that any estimate of habitat suitability without prior critical habitat modeling is subjective and may not be an accurate measure of the area that the taxon can colonize. Numeric estimates are more useful for future trend analyses than are subjective descriptions such as "few," "many," "abundant." Collecting information on a plant's reproductive status, whether the plants are flowering or fruiting, is also valuable in assessing the vigor and reproductive potential of a population. A sketch of the site indicating the plants' locations is helpful for future reference. Location coordinates of each occurrence, and sometimes suboccurrences, are customarily acquired using global positioning system (GPS) technology.

Habitat inventory

Available information on habitat supplied with descriptions of occurrences is generally too diverse and in insufficient detail to make an accurate assessment of the habitat requirements of *Rubus arcticus* ssp. *acaulis*. Essentially, there is an insufficient understanding of all the features that constitute potential habitat to be able to make a rigorous inventory of areas that can actually be colonized in the absence of *R. arcticus* ssp. *acaulis* plants (see Habitat section). The experience on the Bighorn National Forest suggests that specific microhabitat conditions, as yet unidentified, are important. Examples of microhabitat conditions that may affect colonization and persistence of *R. arcticus* ssp. *acaulis* plants include subtle differences in temperature at certain times of the day or night, moisture availability, seasonal shade, and/or soil pH. It is notable that there can be considerable fine-scale spatial variation in soil pH and mineral composition in bogs and fens (Tahvanainen 2005). The habitat descriptions reported with occurrences in Region 2 suggest that, within the restrictions of the eco-climate zones in which it exists, this species grows in a variety of moist to wet habitats. It would likely be prudent to consider any moist to wet areas with organic soils in alpine and sub-alpine regions above 7,000 ft. as potential habitat.

Population monitoring

Elzinga et al. (1998) and Goldsmith (1991) have discussed using rectangular or square quadrat frames along transect lines to effectively monitor the "clumped-gradient nature" of populations such as exhibited by *Rubus arcticus* ssp. *acaulis*. Any monitoring scheme needs to address the patchy and apparently dynamic nature of some of these occurrences. Problems associated with spatial auto-correlation can occur when using permanent plots to monitor a dynamic population. If the size of the plot is too small or the establishment of new plots is not part of the original scheme, then when plants die within the plot and no replacement occurs, it is impossible to know the significance of the change without studying a very large number of similar plots. The appropriate frequency for conducting monitoring studies can be evaluated after sites are visited yearly for several years. If relatively little change has occurred, monitoring the occurrences at longer intervals may be the most time and cost effective schedule but potentially at the cost of some loss of biological and ecological information.

Monitoring studies for *Rubus arcticus* ssp. *acaulis* were initiated in 1999 on the Bighorn National Forest (Fertig 2000b). Trend data were sought to determine the stability of the Sourdough Creek population. A pilot monitoring study was established along Sourdough Creek in 1999 that measured the density, distribution, and number of *R. arcticus* ssp. *acaulis* stems (Fertig 2000b). These studies yielded valuable demographic information (see Distribution and abundance and Demography sections), but the sampling intensity was insufficient to ensure statistical significance even at a cut-off of an 80 percent confidence interval within 20 percent of the population mean (Fertig 2000). The number of plots necessary for high statistical confidence appeared to be prohibitively large. Such a large number of plots would not only be labor intensive but potentially environmentally destructive as the rates of trampling and soil compaction would likely be high. Therefore, annual census of the population whereby each individual is counted was not a practical option due to the taxon's short stature, scattered distribution, and the dense brushy vegetation in its habitat (Fertig 2000b).

The more feasible alternative chosen for the population in Sourdough Creek was to use changes in frequency to measure population trends (Fertig 2000b, Karow personal communication 2004). In this method, the percentage of all plots that are occupied by the species within the sample area is recorded. If a plot is occupied by one or more plants (stems), it is assigned a 1 or if unoccupied assigned a 0. The primary disadvantage of frequency measurements is that plot size strongly influences the results. Frequency scores will be high and shifts in distribution or changes in abundance will be difficult to detect if the plots are too large. Conversely, if the plots are too small, frequency values will be very low and declines in population size will likely go undetected. Choosing a sample size that ensures a baseline frequency of 30 to 70 percent can reduce these problems (Elzinga et al. 1998). An adequate number of plots must be sampled for statistical relevance, and Grieg-Smith (1983) recommended 100 frequency plots per macroplot as a minimum target. For a perennial species, 51 to 156 plots may be sufficient to detect a 10 percent change in frequency over short time intervals (Elzinga et al. 1998. The advantages of the method are that frequency measurements are relatively stable over the growing season, so timing is not a critical factor each year. In addition, it is relatively easy, the key decision being the presence or absence of the taxon, and minimal training is required (Elzinga et al. 1998). There is one significant caveat to using a frequency monitoring method. Both the spatial distribution and the density of a population affect frequency (Grieg-Smith 1983). Therefore, changes are often difficult to interpret biologically. Additional information collected at 5 to 10 year periods may facilitate interpretation. For example, Fertig (2000b) recommended that the population along Sourdough Creek should be remapped to detect gross changes, and detailed notes on abundance, density, habitat, and associated species should be taken periodically.

The frequency with which *Rubus arcticus* ssp. *acaulis* plants occurred in quadrat frames for six plots, designated #1, #1.5, #2, #3, #4, #5 respectively, along Sourdough Creek from 2000 to 2004 have been recorded (Fertig 2000b, Karow personal communication 2004; see Population trend section). These plots contained between 60 and 168 quadrat frames. The chi-square test and McNemar's test have been utilized to test the significance of frequency changes over time in the *R. arcticus* ssp. *acaulis* population at Sourdough Creek (Fertig 2000b). Both are non-parametric methods that require no assumptions about the statistical distribution of the data (Elzinga et al. 1998). Each test utilizes a 2 x 2 contingency table to array the data. However, McNemar's test is applied when the same measuring units are used each year whereas the chi-square test is applied when the sampling units are temporary and taken in a random fashion in each year of measurement (Elzinga et al. 1998). For three of the six plots, (#2, #3, and #4), no changes in frequency were detected using these tests of significance (Karow personal communication 2004). At plot #1.5, an increase was detected between 2002 and 2003, but the frequency with which plants were observed within the quadrat frames declined back to original levels between 2003 and 2004. The populations at these sites may be regarded as stable. Between 2000 and 2004, a significant ($p = 0.05$) decline in frequency was detected at plot #1 whereas plot #5 showed a steady increase in the proportion of quadrats in which plants were observed between 2001 and 2004 (see Population trend section).

Photopoints and photoplots may be useful for supporting monitoring procedures. Photographic documentation is very useful in visualizing large-scale vegetation changes over time and is increasingly used in monitoring plans. However, photographic documentation is not an effective replacement for written observations and quantitative monitoring procedures. Photopoints are collections of photographs of the same field of view that have been retaken from the same position over some given time period. Photoplots are usually relatively close-up photographs showing a bird's-eye-view of the monitoring plot. In both cases, a rebar or some other permanent marker needs to be placed to mark the location where the photographer stands, and compass directions and field-of-view details must be recorded to make sure the photograph can be accurately re-taken. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides and even hardcopies since in less than 50 years time the technology to read currently utilized digital media may no longer be available. In some situations, depending on site conditions, photopoints may not be possible or useful.

Specific monitoring plots with photo-points are very useful not only in areas with recreational or resource extraction activities but also in more pristine areas where the consequences of disturbances such as erosion, landslides, and local soil disturbance can be evaluated.

Habitat monitoring

The relative lack of information on the habitat requirements of *Rubus arcticus* ssp. *acaulis* makes it premature to consider that habitat monitoring in the absence of plants can effectively occur. Habitat monitoring in the presence of plants is customarily associated with population monitoring protocols. Descriptions of habitat should always be recorded during population monitoring activities in order to link environmental conditions with abundance over the long term. Some of the habitat parameters that are useful to record include aspect, slope, availability of perennial or ephemeral water, and the cover by vegetation, including lichen and moss, litter, exposed soil, and rock. The extent of tree canopy cover (shade) is also a useful parameter to record. This measurement can be made using one of two types of spherical densiometers, convex or concave. However, measurements should be made consistently with one or other type because slightly different results can occur between the two instruments, especially if there are different operators. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, where possible it needs to be noted if populations are on an active grazing allotment, even though no use by livestock is observed, or in a camping area, even without the immediate presence of campers. Of course, any signs of herbivory and its source, for example insects or ungulates, are important factors to note. It may also be useful to explain the changes observed in the future if notes are made on whether the area is popular for hiking or if the occurrence is near or adjacent to an apparent trail.

Population or habitat management approaches

No population or habitat management actions have been undertaken specifically for *Rubus arcticus* ssp. *acaulis* in Region 2. Studies using exclosures may be valuable in assessing the impacts of current management practices. Beneficial management practices that the USFS has implemented in general include restricting recreational vehicle traffic and routing hikers to designated trails. In many cases, such policies have been initiated relatively recently, and their consequences have not been documented. It is valuable to monitor sites both before and after management changes, such as the establishment or closure of a trail. It would be useful for future management direction to determine the impacts of the road improvements to the occurrence in the Geneva Park area on the Pike National Forest (U.S. Department of Transportation 2003; see Threats section). The monitoring program would need to be initiated prior to the road and exclosure fence construction and then continue for several years after the activities are completed to determine the long-term effects of the disturbance.

Information Needs

At the present time, *Rubus arcticus* ssp. *acaulis* appears to be a naturally uncommon species within the continental United States. One cannot say with certainty, however, that it has not experienced a decline over the last century or that, given the lack of adequate surveys, it is not currently more common than recognized. The most pressing rangewide need is for more information on the numbers and distribution of this taxon. Present knowledge of its distribution indicates that the occurrences are widely separated from each other in Region 2 and disjunct from the primary population centers. For example, occurrences in central Colorado are several hundred miles away from the nearest site in northern Wyoming, even though there appears to be suitable intervening habitat. Monitoring pre-existing *Rubus arcticus* ssp. *acaulis* sites is essential in order to understand the implications of existing and new management practices. Where management practices are expected to change, collection of baseline data and periodic monitoring conducted after initiation of the new policy would be useful. Inventory and periodic monitoring of existing sites are important to improve understanding of the conservation status of *R. arcticus* ssp. *acaulis*.

The ecology and relative importance of different stages of the life cycle of *Rubus arcticus* ssp. *acaulis* are not known with certainty. Most information has been gathered on the Eurasian *R. arcticus* ssp. *arcticus* and is assumed to apply to subspecies *acaulis*. However, direct studies on *R. arcticus* ssp. *acaulis* are necessary. Current evidence suggests that *R. arcticus* ssp. *acaulis* is a diploid, self-incompatible taxon that has a low frequency of flowering and sets even less fruit. It apparently must achieve its high population size by clonal propagation. These facets of the reproductive biology of *R. arcticus* ssp. *acaulis* need to be confirmed. Within a monitoring protocol, it is particularly important to determine the frequency with which flowering and fruiting occur for each sub-occurrence.

Pollinators appear to be essential for sexual reproduction of *Rubus arcticus* ssp. *acaulis*. Assessing how management practices, such as routine pesticide applications or livestock grazing, may need to be modified to ensure successful cross-pollination may be important to long-term population sustainability. The factors that limit population size and abundance and that contribute to the variable occurrence sizes and patchy spatial distribution are not known and also need to be determined.

The habitat requirements of *Rubus arcticus* ssp. *acaulis* need to be rigorously defined. However, during habitat studies it is very important to be able to detect if the plants experience temporally varying degrees of wetness, for example experiencing extended periods of snowmelt or transitory periods of water inundation in spring, since only one stage in the life cycle may require a high level of water availability. Currently, the apparent dissimilarity in moisture between the habitats that are colonized suggests that there may be significant genetic differences between *R. arcticus* ssp. *acaulis* populations in the different geographic locations.

In summary, research needs for *Rubus arcticus* ssp. *acaulis* include:

❖ gather additional information on abundance and distribution, especially within Region 2

❖ determine long-term trends by monitoring pre-existing occurrences at appropriate intervals

❖ confirm that this taxon is diploid (rather than a sterile triploid) on a population-specific level in Region 2

❖ collect more information on the breeding system, especially if it is self-incompatible (and thus an obligate outcrosser)

❖ gather more information on pollination biology ; in particular identify pollinator species and examine fruit set to see if this taxon is pollinator-limited

❖ rigorously define habitat requirements

❖ identify factors that limit population size and abundance

❖ determine the impact of human activities on populations in order to identify proactive steps towards threat mitigation.

DEFINITIONS

Acidic – has a pH of less than 7.

Alpine – zone occurring above the tree line and below the snow line (Allaby 1992).

Anthropogenic – having to do with or caused by humans.

Apomixis – a type of asexual reproduction in plants, that is reproduction without fertilization or meiosis (Allaby 1992).

Bog – a nutrient-poor, acidic wetland dominated by a waterlogged spongy mat of sphagnum moss that ultimately forms a thick layer of acidic peat; generally has no inflow or outflow; fed primarily by rainwater (U.S. Fish and Wildlife 2005).

Fen – peat-accumulating wetland that generally receives water from surface runoff and (or) seepage from mineral soils in addition to direct precipitation; generally alkaline or slightly acid (U.S. Fish and Wildlife 2005).

Floricanes – the flowering and fruiting growth from the ground up, the cane then being in its second year (Bailey 1941).

Glabrate – "Becoming glabrous in age" (Harrington and Durrell 1986).

Glabrous – "No hairs at all; also used for smooth" (Harrington and Durrell 1986).

Habitat – the part of the physical environment in which a plant or animal lives (U.S. Fish and Wildlife 2005).

Lanceolate – lance-shaped, always several times longer than wide (Harrington and Durrell 1986).

Locus – a specific place on a chromosome where a gene is located (Allaby 1992).

Muskeg – this is used to describe a fragile boggy substrate that consists of dead plants in various stages of decomposition, ranging from fairly intact sphagnum peat moss or sedge peat to highly decomposed muck. Pieces of wood, such as buried tree branches, roots, or whole trees, can make up 5 to 15 percent of the soil.

Polymorphic (polymorphism) – having several different forms.

pH – a measure of acidity and alkalinity of a solution that is a number on a scale on which a value of 7 represents neutrality, lower numbers indicate increasing acidity, and higher numbers indicate increasing alkalinity. Each unit of change represents a tenfold change in acidity or alkalinity and is the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter of the solution.

Phasis (Plural = phases) – "A pronounced difference from what is assumed to be the norm for the species, mostly lacking connected or significant range, that merits recognition but should not be defined in the taxonomic category of variety or form nor be accorded a Latin name" (Bailey, Gentes Herbarum 2: 274). "A phasis is not a systematic subdivision but is included within the definition of a species or variety. Sometimes a phasis is a single colony distinct enough to be recognized; at other times it is a geographical manifestation that can not be defined under a Latin category because of a gradual modification from one region to another" (Bailey 1941).

Pricked –in the horticultural context: To transplant (seedlings for example) before final planting (for example see: "Horticulture Information Leaflet 8504 12/97," available online at: http://www.ces.ncsu.edu/depts/hort/hil/pdf/hil-8504.pdf and "Pennsylvania Commercial Vegetable Production Recommendations for 2005," available online at: http://hortweb.cas.psu.edu/extension/images/PA%2005%20Commercial%20Veg%20Recommends.pdf).

Primocane – shoot from the base of the plant in its first year, usually sterile (Bailey 1941); in its second year, it will flower and fruit and then will be termed a floricane (see above); the foliage is also likely to be different between the two years.

Ranks – from NatureServe and the Heritage Programs' Ranking system (Available online at: http://www.natureserve.org/explorer/granks.htm):

The Global rank of *Rubus arcticus* ssp. *acaulis* is G5T5: G5 indicates that *R. arcticus* is – "Secure-Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals." The status of infraspecific taxa (subspecies or varieties) is indicated by a "T-rank" following the species' global rank. T5 indicates that the subspecies *acaulis* is also "Secure." Rules for assigning T-ranks follow the same principles as the G rank.

Subnational (S) ranks indicate rankings in jurisdictions at the state or provincial level (e.g. California, Ontario).

S1 denotes "Critically Imperiled – Critically imperiled in the subnation because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).

S2 denotes "Imperiled – Imperiled in the nation or subnation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000)."

S3 denotes "Vulnerable – Vulnerable in the subnation either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals."

S4 denotes "Apparently Secure – Uncommon but not rare, and usually widespread in the subnation. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals."

Retuse – "a rounded apex with a shallow notch" (Harrington and Durrell 1986).

Stipitate – bearing a slender stalk-like base, or stipe (Harrington and Durrell 1986).

Stipules – an appendage at the base of the petiole or leaf at each side of its insertion (Harrington and Durrell 1986).

Stochasticity – randomness, arising from chance; Frankel et al. (1995) replaced the word "stochasticity" by "uncertainty" to describe random variation in different elements of population viability.

Type specimen (also holotype) – an individual plant chosen by taxonomists to serve as a basis for naming and describing a new species or variety (Allaby 1992).

Wetlands – lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water; for purposes of this classification, wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979); wetlands generally include swamps, marshes, bogs, and similar areas but also may include land that is currently farmed (Cowardin et al. 1979).

Wetland Regions – US Fish and Wildlife Service wetland regions, not U.S. Fish and Wildlife Service administrative regions. Available online at: http://wetlands.fws.gov/bha/list88.html

Region 1: Connecticut, Delaware, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Virginia, Vermont, West Virginia.
Region 2: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee.
Region 3: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Wisconsin.
Region 4: Montana, North Dakota, South Dakota, Wyoming.
Region 5: Colorado, Kansas, Nebraska.
Region 6: Oklahoma, Texas.
Region 7: Arizona, New Mexico.
Region 8: Colorado, Nevada, Utah.
Region 9: Idaho, Montana, Oregon, Washington, Wyoming
Region 10: California.
Region A: Alaska.
Region C: Puerto Rico.
Region H: Hawaii.
Region V: Virgin Islands.

References

Aiken, S.G., M.J. Dallwitz, L.L. Consaul, C.L. McJannet, L.J. Gillespie, R.L. Boles, G.W. Argus, J.M. Gillett, P.J. Scott, R. Elven, M.C. LeBlanc, A.K. Brysting, and H. Solstad. 2003. Flora of the Canadian Arctic Archipelago: Descriptions, Illustrations, Identification, and Information Retrieval. 1999 onwards. Version: 29th April 2003. Available online at: http://www.mun.ca/biology/delta/arcticf/_ca/www/onepan.htm [Accessed December 2004].

Allaby, M. 1992. The concise Oxford dictionary of Botany, Oxford University Press, New York, NY.

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web: more on the distribution and abundance of animals. University of Chicago Press, Chicago, IL.

Baer, R. 2006. Regional Geologist, Certified Mineral Examiner. USDA Forest Service – Region 2, Lakewood, CO. Personal communication.

Bailey, L.H. 1941. Species Batorum, the genus *Rubus* in North America. Gentes Herbarum. I. Pages 27-30. The Bailey Hortorium, Ithaca, New York, NY.

Bailey, L.H. 1941-1951. Species Batorum, the genus *Rubus* in North America. Gentes Herbarum Vols. 1-5. The Bailey Hortorium, Ithaca, New York, NY.

Baron, J.S. 2001. Acid Rain in the Western United States. Statement of Jill S. Baron, ecologist U.S. Geological Survey. Before the House Committee on Science. United States House of Representatives. May 3, 2001. Available online at: http://www.greennature.com/article.php?sid=869 [Accessed April 2002].

Baron, J.S., H.M Rueth, A.M. Wolfe, K.R. Nydick, E.J. Allstott, J.T. Minear, and B. Moraska. 2000. Ecosystem responses to nitrogen deposition in the Colorado Front Range. Ecosystems 3:352-368.

Baskin, C.C. and J.M. Baskin. 2001. Seeds, ecology, biogeography, and evolution of dormancy and germination. Academic Press, New York, NY.

Blaisdell, J.P. and J.F. Pechanec. 1949. Effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsamroot. Ecology 30:298-305.

Boivin, B. 1955. Etudes batologiques. 1. Sous-genre *Cylactis* (Raf) Focke. Bulletin de la Société Botanique de France. 102:234-236.

Bond W.J. 1995. Assessing the risk of plant extinction due to pollinator and disperser failure. Pages 131-146 *in* J.H. Lawton and R.M. May, editors. Extinction rates. Oxford University Press, New York, NY.

Bornong, B. 2004. Planning Staff Officer, Bighorn National Forest, WY. Personal communication.

Bowman, W.D., T.A. Theodose, J.C. Schardt, and R.T. Conant. 1993. Constraints of nutrient availability on primary production in alpine communities. Ecology 74:2085-2098.

British Columbia Conservation Data Centre. 2004. BC Species and Ecosystems Explorer. Available online at: http://srmapps.gov.bc.ca/apps/eswp/search.do?searchType=PLANT [Accessed June 2004].

Britton, N.L. 1901. Manual of the Flora of the Northern States and Canada. Henry Holt and Company, New York, NY.

Britton. N.L. and A. Brown. 1970. An Illustrated Flora of the Northern United States and Canada. Second edition. Originally published in 1913. Dover Publications. New York. NY.

Buchmann, S.L. and G.P. Nabhan. 1996. The Forgotten Pollinators. Island Press, Washington, D.C.

Campbell, C.S. 2004. Curator, Herbarium at the University of Maine, Orono, ME. Personal communication.

Campbell, C.S., H.P. Adams, P. Adams, A.C. Dibble, L.M. Eastman, S.C. Gawler, L.L. Gregory, B.A. Grunden, A.D. Haines, K. Jonson, S.C. Rooney, T.F. Vining, J.E. Weber, and W.A. Wright. 1995. Checklist of the vascular plants of Maine. Third revision. The Josselyn Botanical Society of Maine, Bulletin 13. Maine Agricultural and Forest Experiment Station, Bulletin 844, University of Maine, Orono, ME.

Cardamone, T. 2002. Aspen Center for Environmental Studies, Aspen, CO. Personal communication.

Carsey, K. 2006. South Zone Botanist. USDA Forest Service Arapaho and Roosevelt National Forests, Boulder, CO.

Center for Native Ecosystems, Colorado Native Plant Society, J. Pollock, Southern Rockies Ecosystem Project, and American Lands Alliance. 2002. Petition for a Rule to List the Porter Feathergrass (*Ptilagrostis porteri*) as Threatened or Endangered under the Endangered Species Act, 16 U.S.C. § 1531 et seq. (1973 as Amended). March 5, 2002. In the Office of Endangered Species, US Fish and Wildlife Service, United States Department of the Interior. Available online at: http://www.nativeecosystems.org/porterfeathergrass/020305_petition.pdf [Accessed December 2005].

Chadde, S.W. 1998. A Great Lakes wetland flora. Pocketflora Press, Calumet, MI.

Chadde, S.W., J.S. Shelly, R.J. Bursik, R.K. Moseley, A.G. Evenden, M. Mantas, F. Rabe, and B. Heidel.1988. Peatlands on national forests in the northern Rocky Mountains: Ecology and conservation. General Technical Report RMRS-GTR-11. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.

Chamberlain, T.C. 1897. The method of multiple working hypotheses. Journal of Geology 5:837-848 (reprinted in Science 148:754-759).

Chapman, S.J., A. Buttler, A-J. Francez, F. Laggoun-Defarge, H. Vasander, M. Schloter, J. Combe, P. Grosvernier, H. Harms, D. Epron, D. Gilbert, and E. Mitchell. 2003. Exploitation of northern peatlands and biodiversity maintenance: a conflict between economy and ecology. Frontiers in Ecology and the Environment 1:525-532.

Charkewicz, S.S. 1981. Bestimmungsbuch der Gefäß-pflanzen Kamtschtakas. Opredelitel sosudistych Rastenii Kamtschatskoi Oblasti. Akademia Nauk SSSR. Isdatelstvo "Nauka", Moskau – personal communication from M. Koltzenburg, Büro für Botanik und Landschaft-sökologie, Tuebingen, Germany, 2004.

Chimner, R.A. and D.J. Cooper. 2003. Carbon dynamics of pristine and hydrologically modified fens in the southern Rocky Mountains. Canadian Journal of Botany 81(5):477-491. [Accessed preprint of published manuscript].

Cholewa, A.F. Curator of Temperate Plants, J.F. Bell Museum of Natural History, University of Minnesota, St. Paul, MN.

Cody, W.J. 1996. Flora of the Yukon Territory. NRC.CNRC, NRC Research Press, Ottawa, Ontario, Canada.

Cody, W.J., C.E. Kennedy, and B. Bennett. 1998. New records of vascular plants in the Yukon Territory. The Canadian Field-Naturalist 112(2):289-328.

Cody, W.J., C.E. Kennedy, and B. Bennett. 2001. New records of vascular plants in the Yukon Territory III. The Canadian Field-Naturalist 115:301-322.

Cody, W.J., C.E. Kennedy, and B. Bennett. 2002. New records of vascular plants in the Yukon Territory IV. The Canadian Field-Naturalist 116:446-474.

Cogbill, C.V. 1985. Dynamics of the boreal forests of the Laurentian Highlands, Canada. Canadian Journal of Forest Research. 15:252-261.

Colorado Department of Agriculture. Undated. Colorado's Noxious Weed Management Program. Colorado Department of Agriculture, Lakewood, CO. Available online at: http://www.colostate.edu/Depts/ SoilCrop/ extension/CEPEP/noxious_weeds.htm [Accessed May 2003].

Colorado Natural Heritage Program. 2003. Element occurrence record data compilation for *JnJ Associates* LLC, completed February 2003. Colorado Natural Heritage Program, Fort Collins, CO.

Colorado Natural Heritage Program. 2004. On-line Rare Plant Guide, Fort Collins, CO. Available online at: http: //ndis.nrel.colostate.edu/ndis/rareplants [Accessed January, 2004].

Comer, P., K. Goodin, A. Tomaino, G. Hammerson, G. Kittel, S. Menard, C. Nordman, M. Pyne, M. Reid, L. Sneddon, and K. Snow. 2005. Biodiversity Values of Geographically Isolated Wetlands in the United States. NatureServe, Arlington, VA. Available online: http://www.natureserve.org/library/isolated_wetlands_05/ isolated_wetlands.pdf [Accessed December 2005].

Cooper, D.J. 1996. Water and soil chemistry, floristics, and phytosociology of the extreme rich High Creek fen, in South Park, CO. Canadian Journal of Botany 74:1801-1811.

Cooper, D.J. and R.E. Andrus. 1994. Patterns of vegetation and water chemistry in peatlands of the west-central Wind River Range, WY. Canadian Journal of Botany 72:1587-1597.

Cooper, D.J. and L.H. MacDonald, 2000. Restoring the vegetation of mined peatlands in the Southern Rocky Mountains of Colorado. Restoration Ecology 8:103-111.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. December 1979. US Department of the Interior, Fish and Wildlife Service, Washington, D.C. Also made available online by the Northern Prairie Wildlife Research Center, Jamestown, ND: Online at: http://www.npwrc.usgs.gov/resource/1998/classwet/classwet.htm (Version 04DEC98).

Curtis, J.T. and M.L. Partch. 1950. Some factors affecting flower production in *Andropogon gerardii*. Ecology 31: 488-489.

Damman, H. and M.L. Cain. 1998. Population growth and viability analyses of the clonal woodland shrub, *Asarum canadense*. Journal of Ecology 86:13-26.

Daubenmire, R. 1978. Plant geography, with special reference to North America. Academic Press, New York, NY.

Davis, P.T. 2003. Abrupt late Pleistocene climatic reversals in Colorado and Wyoming: evidence from lake sediments and moraines in cirques. Abstract No. 139-9. The Geological Society of America 35(6):350.

Dawson, D.K. 1979. Bird communities associated with succession and management of lowland conifer forests. Pages 120-131 *in* Management of north central and northeastern forests for nongame birds. Proceedings of the workshop, January 23-25 1979, Minneapolis, MN. R.M. DeGraaf and K.E. Evans (compilers). General Technical Report NC-51. USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN.

Dayton, W.A. 1931. Important western browse plants. Miscellaneous Publication 101. Washington, D.C.

Dorn, R.D. 1984. Vascular plants of Montana. Mountain West Publishing, Cheyenne, WY.

Dorn, R.D. 2001. Vascular plants of Wyoming. 3rd ed. Mountain West Publishing, Cheyenne, WY.

Douglas, G.W., D. Meidinger, and J. Pojar. 1999. Illustrated flora of British Columbia. Volume 4, Dicotyledons (Orobanchaceae through Rubiaceae). B.C. Ministry of Environment, Lands and Parks and Ministry of Forestry, Victoria, British Columbia, Canada.

Edwards, J. 1985. Effects of herbivory by moose on flower and fruit production of *Aralia nudicaulis*. Journal of Ecology 73:861-868.

Ellstrand, N. and M.L. Roose. 1987. Patterns of genotypic diversity in clonal plant species. American Journal of Botany 76:123-131.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1. U.S. Department of Interior, Bureau of Land Management, Denver, CO.

Environmental Media Services. 2001. Definitions for Public Land Designations, Last update: April 27, 2001. Available online at: www.ems.org [Accessed December 2003].

Erikkson, O. 1994. Stochastic population dynamics of clonal plants: numerical experiments with ramet and genet models. Ecological Research 9:257-268.

Ervi, L.O., P. Hanigia, and E. Kivinen. 1955. Mesimarjan (*Rubus arcticus* L.) marjontaa koskevia tutkimuksia. Acta Agr. Fenn. 83:93-112 (in Finnish). *In*: J. Tammisola. 1988. Incompatibility classes and fruit set in natural populations of arctic bramble (*Rubus arcticus* L.) in Finland. Journal of Agricultural Science in Finland 60(5): 327-446.

Fernald, M.L. 1925. Persistence of plants in unglaciated areas of boreal America. Memoirs of the American Academy of Arts and Sciences 15(3):239–342.

Fernald. M.L. 1950. Gray's Manual of Botany. American Book Co., New York, NY.

Fertig, W. 2000a. *Rubus acaulis* – Nagoonberry, State Species Abstract. Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY. Available online at: http://uwadmnweb.uwyo.edu/wyndd/ [Accessed February 2004].

Fertig, W. 2000b. Ecological assessment and monitoring program for northern blackberry (*Rubus acaulis*) in the Bighorn National Forest, Wyoming. Wyoming Natural Diversity Database, Laramie, WY. Available online at: http://uwadmnweb.uwyo.edu/wyndd/ [Accessed July 2004].

Fertig, W., C. Refsdal, and J. Whipple. 1994. Wyoming Rare Plant Field Guide (Version 16JUL97). Wyoming Rare Plant Technical Committee, Cheyenne. Northern Prairie Wildlife Research Center, Jamestown, ND. Available online at: http://www.npwrc.usgs.gov/resource/plants/wyplant/wyplant.htm.

Fertig, W. and Wyoming Rare Plant Technical Council. 1994. Wyoming rare plant field guide. Prepared for Bureau of Land Management - Cheyenne, U.S. Fish and Wildlife Service - Cheyenne, Forest Service - Intermountain Region, Forest Service - Rocky Mountain Region, National Park Service - Rocky Mountain Region, Wyoming Game and Fish Department, Wyoming Natural Diversity Database, The Nature Conservancy - Laramie, WY.

Finn, C. 1999. Temperate berry crops. Pages 324–334 *in* J. Janick, editor. Perspectives on new crops and new uses. American Society for Horticultural Science Press, Alexandria, VA.

Flinn, M.A. and R.W. Wein. 1977. Depth of underground plant organs and theoretical survival during fire. Canadian Journal of Botany 55:2550-2554.

Focke, W.O. 1910. Species *Ruborum*. Monographiae generis *Rubi* prodromus. part I. Bibliotheca Botanica. 17 (Ht. 72):1-120. [*Rubus acaulis* ssp. *acaulis* pages 24-25].

Focke, W.O. 1911. Species *Ruborum*. Monographiae generis *Rubi* prodromus. part II. Bibliotheca Botanica. 17(Ht. 72):121–223.

Focke, W.O. 1914. Species *Ruborum*. Monographiae generis *Rubi* prodromus. Bibliotheca Botanica. 19(Ht.83):224-498 (pages sometimes cited as 1-274).

Forester, K.G. 2004. USDA Forest Service, Bighorn National Forest, Sheridan, WY. Personal communication.

Frankel, O.H., A.H.D. Brown, and J.J. Burdon. 1995. The conservation of plant biodiversity. P. 127. Cambridge University Press, New York, NY.

Fredrickson, E. 2004. Livestock Foraging Ecology. Page Modified: 08/12/2004. USDA Agricultural Research Service. Available online at: http://www.ars.usda.gov/Main/docs.htm?docid=5565 [Accessed December 2005].

Gitzendanner, M.A. and P.S. Soltis. 2000. Patterns of genetic variation in rare and widespread plant congeners. American Journal of Botany 87(6):783-792.

Gleason, H.A. 1963. The New Britton and Brown Illustrated Flora of the Northeastern United States and adjacent Canada. Volume 2. Hafner Publishing Co., New York, NY.

Gleason, H.A. and A. Cronquist. 1991. Manual of Vascular Plants of the Northeastern United States and Adjacent Canada. Pages 250-251. The New York Botanical Garden, Bronx, NY.

Goldsmith, F.B. 1991. Monitoring for conservation and ecology. Chapman and Hall, New York, NY.

Granstrom, A. 1987. Seed viability of fourteen species during five years of storage in a forest soil. Journal of Ecology 75:321-331.

Grant, V. 1981. Plant speciation. Second edition. Columbia University Press, New York, NY.

Grieg-Smith, P. 1983. Quantitative plant ecology. Studies in Ecology 9:47-53.

Grime, J.P., J.G. Hodgson, and R. Hunt. 1988. Comparative plant ecology - a functional approach to common British species. Allen and Unwin, Inc., Winchester, MA.

Haines, A. and T.F. Vining 1998. Flora of Maine. V.F. Thomas Co., Bar Harbor, ME.

Harper, J.L. 1977. Population Biology of Plants. Academic Press, London, U.K.

Harrington, H.D. 1964. Manual of the plants of Colorado. Second edition. Sage Books, Chicago, IL.

Harrington, H.D. and L.W. Durrell. 1986. Reprint. Swallow Press, Athens, OH.

Hartman, E. and M.L. Rottman. 1984. Noteworthy collections. Madrono 32(3):191-193.

Heinrich, B. 1976. The foraging specializations of individual bumble bees. Ecological Monographs 46:105-128.

Heinselman, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research 3:329-382.

Hillborn, R. and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, NJ.

Hitchcock, C.L. and A. Cronquist. 2001. Reprint. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Holmes, R. 2004. Regional Botanist, USDA Forest Service, Portland, OR. Personal communication.

Hultén, E. 1946. *Rubus*. The Flora of Alaska and Yukon 6:992-995.

Hultén, E. 1968. Flora of Alaska and neighboring territories. Stanford University Press, Stanford, CA. Pages 340-341.

Huxley. A. 1992. The New RHS Dictionary of Gardening. MacMillan Press, England, U.K.

Kangasjärvi, J. and J. Oksanen 1989. Pollinator behaviour in cultivated and wild Arctic bramble (*Rubus arcticus* L.). Journal of Agricultural Science in Finland 61:33-38.

Karp, K.M. 1997. The distribution and habitats of the Arctic bramble. Baltic Forestry 3(2):48-52.

Karp, K., M. Starast, and R. Varnik. 1997. The Arctic bramble (*Rubus arcticus* L.) - the most profitable wild berry in Estonia. Baltic Forestry 3(2):47.

Karron, J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. Pages 87-98 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Kartesz, J. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. Volume 1 - Checklist. Second edition. Timber Press, Portland, OR.

Kearns, C.A., D.W. Inouye, and N.M. Waser. 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. Annual Review of Ecology and Systematics 29:83-112.

Keiding, N. 1975. Extinction and exponential growth in random environments. Theoretical Population Biology 8: 49-63.

Kershaw, L., A. MacKinnon, and J. Pojar. 1998. Plants of the Rocky Mountains. Lone Pine Publishing, Edmonton, Alberta, Canada.

Kettler, S.M., N.D. Lederer, D. Bacher, and S. Spackman. 1993. Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, plants of special concern. Unpublished document. December. Colorado Natural Heritage Program, Boulder, CO.

Kingsolver, R.W. 1986. Vegetative reproduction as a stabilizing feature of the population dynamics of *Yucca glauca*. Oecologia 69:380-387.

Kokko, H., A. Lemmetty, P. Haimi, and S. Karenlampi. 1996. New host for raspberry bushy dwarf virus: Arctic bramble (*Rubus arcticus*). European Journal of Plant Pathology 102:713-717.

Kollmann, J., T. Steinger, and B.A. Roy. 2000. Evidence of sexuality in European *Rubus* (Rosaceae) species based on AFLP and allozyme analysis. American Journal of Botany 87:1592-1598.

Koltzenburg, M. 2004. Büro für Botanik und Landschaftsökologie, Mitglied im Berufsverband der Landschaftsökologen, Tuebingen, Germany. Personal communication.

Kukk, Ü. 2001. Monitoring of vascular plants in Estonia. Planta Europa Conference III, Pruhonice, Czech Republic June 2001. Available online at: http://www.plantaeuropa.org/html/conference_2001/conference_poster_pres.htm [Accessed May 2003].

Landes, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Larsson, E.G.K. 1969. Experimental taxonomy as a base for breeding in northern *Rubi*. Hereditas 63:283-351.

Latvian Environment Data Centre. 2000. Extinct Species in The Red Data Book of Latvia - *Rubus arcticus*. Available online at: http://www.grida.no/enrin/biodiv/biodiv/national/latvia/species/table_2.htm [Accessed June 2004].

Legal Information Institute. Undated. Syllabus for Solid Waste Agency of Northern Cook County (SWANCC) v. United States Army Corps of Engineers et al. Certiorari to the United States Court of Appeals for the Seventh Circuit. No. 99—1178. Argued October 31, 2000–Decided January 9, 2001. Legal Information Institute, Cornell Law School, Myron Taylor Hall, Ithaca, NY. Available online at: http://www.law.cornell.edu/supct/html/99-1178.ZS.html [Accessed November 2005].

Lenz, J., T. Gotthardt, M. Kelly, and R. Lipkin. 2001. Vascular plant and vertebrate species lists from NPSpecies as of September 30, 2001 for Denali National Park and Preserve. Unpublished Report for the National Park Service, Inventory and Monitoring Program, Alaska Region. Alaska Natural Heritage Program, Environment and Natural Resources Institute, University of Alaska, Anchorage, AK.

Lesica, P. and J.S. Shelly. 1991. Sensitive, threatened and endangered vascular plants of Montana. Occasional Publications of the Montana Natural Heritage Program. No. 1. Montana Natural Heritage Program, Helena, MT.

Lindqvist-Kreuze, H., H. Koponen, and J.P.T. Valkonen. 2003. Genetic diversity of arctic bramble (*Rubus arcticus* L. subsp. *arcticus*) as measured by amplified fragment length polymorphism. Canadian Journal of Botany 81(8): 805-813.

Linnaeus (Caroli Linnaei). 1753. *Rubus*. Species Plantarum. Vol 1:492-494.

Linnaeus, C. 1753. Species Plantarum: 708. *In*: Focke (1910).

Lipkin, R. 2003. Alaska Natural Heritage Program, University of Alaska, Anchorage, AK. Personal communication.

Liston, A. 2004. Professor, Department of Botany and Plant Pathology, Oregon State University. Corvallis, OR. Personal communication.

Löve, Á. 1987. Chromosome number reports XCVI. Taxon 36(3):659-661.

Love, J.D. and A.C. Christiansen. 1985. Geologic map of Wyoming. US Geological Survey, Denver, CO.

Mabberley, D.J. 1997. The Plant-Book. Second edition. Cambridge University Press, Cambridge, England, U.K.

MacArthur, R.H. and E.D. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, NJ.

Maine Natural Areas Program. 2004. Sensitive plant species list. Available online at: http://www.state.me.us/doc/nrimc/mnap/staff/biograph.htm [Accessed May 2004].

McDowell, S.C.L. 2002. Photosynthetic characteristics of invasive and noninvasive species of *Rubus* (Rosaceae). American Journal of Botany. 89:1431-1438.

McGraw, J.B. and M.C. Vavrek.1989. Buried viable seeds in Artic and alpine communities. Page 96 *in* M.A. Leck, V.T. Parker, and R. L. Simpson, editors. Ecology of soil seed banks. Academic Press Inc, San Diego, CA.

Menges, E.S. 1991. The application of minimum viable population theory to plants. Pages 45-61 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Menges, E.S. 2000. Population viability analyses in plants: challenges and opportunities. Trends in Ecology and Systematics 15:51-56.

Michaux, A. 1803. Isocandria, Polygynia, *Rubus* L. Flora Boreali-Americana (Michaux) 1:296-298 .

Michigan Natural Features Inventory. 2005. Michigan special plants. Michigan Natural Features Inventory, Michigan State University Extension Service. Available online at: http://web4.msue.msu.edu/mnfi/data/county.cfm (direct web page to *Rubus acaulis*: http://web4.msue.msu.edu/mnfi/data/rareplants.cfm?el=PDROS1K8F0) [Accessed December 2005].

Montana Natural Heritage Program. 2005. Montana Plant Field Guide - *Rubus arcticus*. Available online at: http://nhp.nris.state.mt.us/plants/plantguide_nd.asp?species=12417 [Accessed December 2005].

Mosquin, T. and J.E.H. Martin 1967. Observations on the pollination biology of plants on Melvile Island, NWT, Canada. The Canadian Field Naturalist 81(3):201-205.

Mueggler, W.F. 1967. Response of mountain grassland vegetation to clipping in southwestern Montana. Ecology 48: 942-494.

Murray, M.P. 1997. High Elevation Meadows and Grazing: Common Past Effects and Future Improvements. International Journal of Wilderness 3(4):24-27.

Nagy, J.A., A.M. Pearson, B.G. Goski, and W.J. Cody. 1979. Range extensions of vascular plants in Northern Yukon Territory and northwestern District of Mackenzie. Canadian Field-Naturalist 93(3):259-265.

Napolitano, M.B. 1998. Persistence of Historical Logging Impacts on Channel Form in Mainstem North Fork Caspar Creek. *In*: C.A. Ukiah, R.R. Ziermer, technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek Story. General Technical Report PSW-GTR-168. USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

National Park Service. Undated. The National Park System, Caring for the American Legacy. Available online at: http://www.nps.gov/legacy/mission.html [Accessed December 2005].

National Park Service Organic Act, 16 U.S.C.1. The National Park Service Organic Act is an act to establish a National Park Service, and for other purposes. The title is not an official short title but merely a popular name used for convenience. The Act has no official short title. The National Park Service Organic Act (16 U.S.C. l 2 3, and 4), as set forth herein, consists of the Act of August 25, 1916 (39 Stat. 535) and amendments thereto. Further information available online at: http://www.nps.gov/legacy/organic-act.htm [Accessed November 2005].

NatureServe. 2004. NatureServe Explorer: An online encyclopedia of life [web application]. Version 3.1. NatureServe, Arlington, Virginia. Available online at: http://www.natureserve.org/explorer [Accessed: June 1, 2004].

New York Botanical Garden. Herbarium records. Available online at: http://scisun.nybg.org [Accessed May 2004].

Newsholme, C. 2002. Willows, the genus *Salix*. Timber press, Portland, OR.

Nicholoff, S.H., compiler. 2003. Wyoming Bird Conservation Plan, Version 2.0. Wyoming Partners in Flight. Wyoming Game and Fish Department, Lander, WY. Available online at: http://www.blm.gov/wildlife/plan/WY/Wyoming%20Bird%20Conservation%20Plan.htm Specifically Meadow section at: http://www.blm.gov/wildlife/plan/WY/Meadows.pdf [Accessed December 2005].

Norrdahl, K., T. Klemola, E. Korpimäki, and M. Koivula. 2002. Strong seasonality may attenuate trophic cascades: vertebrate predator exclusion in boreal grassland. Oikos 99:419-430.

Nybom, H. and B.A. Schaal. 1990. DNA "fingerprints" reveal genotypic distributions in natural populations of blackberries and raspberries (*Rubus*, Rosaceae). American Journal of Botany 77:883-888.

Oliver, C.D. and B.C. Larson. 1996. Forest Stand Dynamics. Updated Edition. John Wiley and Sons, Inc., New York, NY.

Oregon Herbarium Network. 2005. Oregon Vascular Plant Database Results- Database last updated: 28 April 2005. Oregon State University Herbarium, Corvallis, OR. Available online at: http://ocid.nacse.org/cgi-bin/qml/herbarium/plants/vherbgenus.qml [Accessed December 2005].

Oregon Natural Heritage Information Center. 2004. Sensitive plant species list. Available online at: http://oregonstate.edu/ornhic/data/vascular.html [Accessed May 2004].

Osborne, J.L., S.J. Clark, R. Morris, I. Williams, R. Riley, A. Smith, D. Reynolds, and A. Edwards. 1999. A landscape-scale study of bumble bee foraging range and constancy, using harmonic radar. Journal of Applied Ecology 36: 519-533.

Plants For A Future. 2004. Species Database, 1997-2003. Plants for a Future, Blagdon Cross, Ashwater, Beaworthy, Devon, UK. Available online in the UK at: http://www.comp.leeds.ac.uk. Available online in the US at: http://www.ibiblio.org/pfaf/cgi-bin/find_lat?ALL=rubus+arcticus [Accessed May 2004].

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Platt, W.J., G.R. Hill, and S. Clark. 1974. Seed production in a prairie legume (*Astragalus canadensis* L.). Oecologia (Berl.) 15:55-63.

Pollard, J.H. 1966. On the use of the direct matrix product in analyzing certain stochastic population models. Biometrika 53:397-415.

Polunin, N. 1959. Circumpolar Arctic flora. Oxford University Press, London, England, U.K.

Porsild, A.E. 1951. Botany of southeastern Yukon adjacent to the Canol Road. Natural Museums of Canada Bulletin 121:1-400.

Porsild, A.E. and W. Cody. 1980. Checklist of the vascular plants of the Northwest Territories Canada I-viii:1-607.

Proctor, J. 2004-2005. Botanist. Medicine Bow-Routt National Forest and Thunder Basin National Grassland, Laramie, WY. Personal communications.

Ratchford, J.S., S.E. Wittman, E.S. Jules, A.M. Ellison, N.J. Gotelli, and N.J. Sanders. 2005. The effects of fire, local environment and time on ant assemblages in fens and forests. Diversity and Distributions 11:487–497. Available online at: ttp://web.utk.edu/~nsanders/Pubs/Ratchford.pdf [Accessed December 2005].

Rafinesque-Schmaltz, C.S. 1819. Rosaceae, *Cylactis*. American Journal of Science 377.

Ramsey, G., C.E. Thompson, S. Neilson, and G.R. Mackay. 1999. Honeybees as vectors of GM oilseed rape pollen. *In*: Gene flow and Agriculture: Relevance for Transgenic Crops. P.J.W. Lutman, editor. BCPC Symposium Proceedings no. 72. British Crop Protection Council, Farnham, U.K.

Rintoul, J. 2003. Section Head and Information Coordinator, Alberta Natural Heritage Information Centre, Parks and Protected Areas Division, Alberta Community Development, Alberta, Canada. Personal communication.

Roche, K. 2004-2005. Ecologist. Medicine Bow-Routt National Forest and Thunder Basin National Grassland, Laramie, WY. Personal communications.

Rueth, H.M. and J.S. Baron. 2002. Differences in Engelmann spruce forest biogeochemistry east and west of the Continental Divide in Colorado. Ecosystems 5:45-57.

Ryke, N., L. McMartin, and D. Winters. 1993. Threatened, endangered, and sensitive species list for the Pike and San Isabel National Forests and Comanche and Cimarron grasslands. Unpublished document. USDA Forest Service, Denver, CO.

Ryynänen, A. 1972. Arctic bramble (*Rubus arcticus* L.), a new cultivated plant. Annales Agricultural Fenniae 11:170-173.

Ryynänen, A. 1973. *Rubus arcticus* and its cultivation. Annales Agriculturae Fenniae 12. Pages 1-76.

Saastamoinen, S. 1930. Mesiimarja (*Rubus arcticus* L.) Suomessa. Referat: Die nordische Himbeere (*Rubus arcticus* L) in Finnland. Annales societatis zoologicæ-botanicæ Fennicaæ Vanamo 13:356-414.

Schulman, L. 2004. Director, Botanic Garden at the University of Helsinki, Finland. Personal communication.

Scoggan, H.J. 1950. The flora of Bic and the Gaspe Peninsula, Quebec. Bulletin no. 115, Biological Series No. 39. Canadian Department of Resources and Development, Ottawa, Canada.

Scoggan, H.J. 1957 Flora of Manitoba. National Museum of Canada Bulletin no. 140, p. 351-353. Department of Northern Affairs and National Resources, Ottawa, Ontario, Canada.

Scoggan, H.J. 1978 Dicotyledonae (Saururaceae to Violaceae). The Flora of Canada 3:547-1115.

Seymour, F.C. 1969. The Flora of New England. The Charles E. Tuttle Co. Publishers, Rutland, VT.

Sheley, R.L. and J.K. Petroff.1999. Biology and management of noxious rangeland weeds. Oregon State University Press, Corvallis, OR.

Soper, J.H. and M.L. Heimburger. 1982. Shrubs of Ontario. Pages 227-229. National Museum of Natural Sciences, Ottawa, Canada.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, the USDA Forest Service, and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Stace, C. 1997. New Flora of the British Isles. Second edition. Cambridge University Press, Cambridge, England, U.K.

Sugden, E.A. 1985. Pollinators of *Astragalus monoensis* Barneby (Fabaceae): new host records; potential impact of sheep grazing. Great Basin Naturalist 45(2):299-312.

Sullivan, J. 1994. Conifer bog. *In*: Fire Effects Information System, [Online]. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/ [Accessed November 2004].

Sumerlin, D. 2004. Wildlife Biologist, Sulphur Ranger District, USDA Forest Service Arapaho National Forest, Granby, CO. Personal communication.

Supreme Court of the United States. 2001. Solid Waste Agency of Northern Cook County (SWANCC) v. United States Army Corps of Engineers et al. Certiorari to the United States Court of Appeals for the Seventh Circuit. No. 99—1178. Argued October 31, 2000–Decided January 9, 2001. Published by the Legal Information Institute, Cornell University Law School. Available online at: http://www.law.cornell.edu/supct/html/99-1178.ZS.html [Accessed November 2005].

Tammisola, J. 1988. Incompatibility classes and fruit set in natural populations of arctic bramble (*Rubus arcticus* L.) in Finland. Journal of Agricultural Science in Finland 60(5):327-446.

Tammisola, J. and A. Ryynänen. 1970. Incompatibility in *Rubus arcticus* L. Hereditas 66:269-278.

Tahvanainen, T. 2005. Diversity of water chemistry and vegetation of mires in the Kainuu region, middle boreal Finland. PhD dissertation no. 33. University of Jeonsuu, Jeonsuu, Finland. Available online at: http://bio.joensuu.fi/PhD/tahvanainen.pdf [Accessed December 2005].

Taylor, R.J. 1990. Northwest weeds. Mountain Press Publishing Company, Missoula, MT.

Theodose, T.A. and W.D. Bowman. 1997. Nutrient availability, plant abundance, and species diversity in two alpine tundra communities. Ecology 78(6):1861-1872.

Thompson, K. 1992. The functional ecology of seed banks. Pages 231-258 *in* M. Fenner, editor. Seeds: The Ecology of Regeneration in Plant Communities. CAB International, Wallingford, Oxon, UK.

Tiner, R.W., H.C. Bergquist, G.P. DeAlessio, and M.J. Starr. 2002. Geographically Isolated Wetlands: A Preliminary Assessment of their Characteristics and Status in Selected Areas of the United States. US Department of the Interior, Fish and Wildlife Service, Northeast Region, Hadley, MA. Available online at: http://wetlands.fws.gov/Pubs_Reports/isolated/report.htm [Accessed December 2005].

Tweto, O. 1978. Geologic map of Colorado. US Geological Survey, Denver, CO.

United Nations Economic Commission for Europe. 1998. Environmental performance review of Latvia. Committee on Environmental Policy. As discussed and approved by the five sessions of the Committee on Environment Policy October 1998.

University of Alaska Museum Herbarium. 2005. Arctos. Data on northern specimen-based research. Last modified 3 May 2005 by Alan Batten. The University of Alaska Museum at the University of Alaska Fairbanks, Fairbanks, AK. Available online at: http://arctos.database.museum/SpecimenResults.cfm [Accessed December 2005].

University of Maine Herbarium. 2004. Herbarium online database, University of Maine, Orono, ME. Available online at: http://www.umesci.maine.edu/biology/herbarium/plant-database/listing.asp [Accessed July 2004].

U.S. Environmental Protection Agency. 1977. Clean Water Act (CWA). Available online at: http://www.epa.gov/owow/wetlands/laws/ [Accessed December 2005].

U.S. Department of Transportation. 2003. Guanella Pass Road. FHWA-FPCO-EIS-99-01-F. Record of Decision. Available online at: http://www.cflhd.gov/projects/co/guanella/ROD.cfm [Accessed December 2005].

U.S. Environmental Protection Agency 1997. Climate Change and Colorado. EPA 230-F-97-008f. Office of Policy, Planning and Evaluation, Climate and Policy Assessment Division, Washington, D.C.

U.S. Environmental Protection Agency. 1998. Climate Change and Wyoming. EPA 236-F-98-007n. Office of Policy, Planning and Evaluation, Climate and Policy Assessment Division, Washington, D.C.

U.S. Fish and Wildlife Service. 1981. US Fish and Wildlife Service Mitigation Policy published in the Federal Register, Vol. 46, No. 15, January 23, 1981, as corrected in the Federal Register of February 4, 1981. See U.S. Fish and Wildlife Service summaries available online at: http://www.fws.gov/policy/ser500.html [Accessed January 2005].

U.S. Fish and Wildlife Service. 1993. 501 FW 2, Mitigation Policy FWM#: 069 (new), Date: February 24, 1993. Available online at: http://www.fws.gov/policy/501fw2.html [Accessed November 2005].

U.S. Fish and Wildlife Service. 2005. Branch of Habitat Assessment- Providing Wetland and other Habitat Information to the American People. Last Modified April 05, 2005. Available online at: http://wetlands.fws.gov. Specifically see map outlining Wetland regions: http://wetlands.fws.gov/bha/list88.html [Accessed December 2005].

U.S. Fish and Wildlife Service. Undated. Regional Boundaries. Available online at: http://www.fws.gov/where/ [Accessed July 2004].

USDA Forest Service. 1933. A National Plan for American Forestry. U.S. Senate Document No. 12, 73d Congress, 1st session, 1933. 2 volumes.

USDA Forest Service. 1984. Final Impact Environmental Impact Statement. Pike and San Isabel National Forests; Comanche and Cimarron National Grasslands. USDA Forest Service, Pueblo, CO.

USDA Forest Service. 1986. Hiawatha Forest Plan. Hiawatha National Forest, Escanaba, MI. Page Last Updated: May 28, 2004. Available online at: http://www.fs.fed.us/r9/hiawatha/revision/current_plan/welcome_plan.html [Accessed May 2004].

USDA Forest Service. 1988. Range Plant Handbook. Dover Publications, Inc., New York, NY.

USDA Forest Service. 1994. Forest Service Manual, Title 2600-Wildlife, Fish and Sensitive Plant Habitat Management; Region 2 Supplement 2600-94-2, Section 2672.11a, Exhibit 1.

USDA Forest Service. 1999. Regional Forester's Sensitive Species Plant List for Region 6 (Pacific Northwest Region). Unpublished document.

USDA Forest Service. 2002. Conservation Assessment for Arctic Raspberry (*Rubus acaulis*) Michx. USDA Forest Service, Eastern Region. Available online at: http://www.fs.fed.us/r9/wildlife/tes/ca-overview/docs/plant_rubus_acaulis-Artic_Raspberry.pdf [Accessed March 2004].

USDA Forest Service. 2003a. Forest Service Manual 2600 – Chapter 2670 – Threatened, Endangered, and Sensitive Plants and Animals, Supplement No.: 2600-2003-1, Effective Date: December 1, 2003. Unpublished document USDA Forest Service, Rocky Mountain Region (Region 2), Denver, CO.

USDA Forest Service. 2003b. Regional Forester Sensitive Plants, Region 9. Signed by Regional Forester on 29 February 2000, list maintenance on 20 October 2003. Available online at: http://www.fs.fed.us/r9/wildlife/tes/docs/rfss_plants.pdf [Accessed December 2005].

USDA Forest Service. FY 2004-2008. Bighorn National Forest, rare plant management strategy – 5 year action plan. Unpublished document. USDA Forest Service. Bighorn National Forest, WY.

USDA Forest Service. 2004a. USDA Forest Service Strategic Plan for Fiscal Years 2004-08 Publication FS-810. USDA Forest Service, Washington, D.C.

USDA Forest Service. 2004b. Forest Plan Revision on the Hiawatha National Forest. Last update April 13, 2004. Available online at: http://www.fs.fed.us/r9/hiawatha/revision/rev_welcome.html [Accessed June 2004].

USDA Forest Service. 2005. Forest Service Sensitive Species that are not listed or proposed species under the ESA, 31 October 2005. Available online at: http://www.fs.fed.us/biology/tes/ [Accessed November 2005].

USDA, NRCS. 2004. The PLANTS Database, Version 3.5 National Plant Data Center, Baton Rouge, LA 70874-4490. Internet site: http://plants.usda.gov. [Accessed July 2004].

USGS Northern Prairie Wildlife Research Center. Undated. Wyoming Rare Plant Field Guide, Species by Vegetation Type. Available online at: http://www.npwrc.usgs.gov/resource/distr/others/wyplant/habsoil.htm [Accessed March 2004].

Viereck, L.A. and E.L. Little, Jr. 1972. Alaska trees and shrubs. Agricultural Handbook. 410. USDA Forest Service, Washington, D.C.

Wagner, W.H. and J.M. Beitel. 1993. Lycopodiaceae Mirbel, Club moss Family. Flora of North America (Pteridophytes and Gymnosperms). Volume 2:18-37.

Washington Natural Heritage Program. 2004. Rare Plants Information. Washington Natural Heritage Program. Washington Department of Natural Resources, Olympia, WA. Available online at: www.dnr.wa.gov/nhp/ [Accessed June 2004].

Weber, H.E. 1995. *Rubus*. *In*: H.J. Conert and G. Hegi, editors. Illustrierte Flora von Mitteleuropa. Third edition, vol. 4.2a. Blackwell, Berlin, Germany.

Weber, W.A. 1960. The Middle Asian Element in the Southern Rocky Mountain Flora of the western United States: a critical biogeographical review. Journal of Biogeography 30:649–685.

Weber, W.A. 1985. New names and combinations, principally in the Rocky Mountains flora-V. Phytologia 58(6):382-384.

Weber, W.A. and R.C. Wittmann. 2001a. Colorado Flora, eastern slope. Third edition. University Press of Colorado, Boulder, CO.

Weber, W.A. and R.C. Wittmann. 2001b. Colorado Flora, western slope. Third edition. University Press of Colorado, Boulder, CO.

Welsh, S.L. 1974. Anderson's Flora of Alaska and adjacent parts of Canada. Brigham Young University Press, Provo, UT. Pages 408-409.

Whelan, R.J. 1997. The Ecology of Fire. Cambridge University Press, New York, NY.

Whipple, J. 2006. Botanist. Yellowstone National Park, WY. Personal communication.

Whitson, T.D., L.C. Burrill, S.A. Dewey, D.W. Cudney, B.E. Nelson, R.D. Lee, and R. Parker. 1991. Weeds of the West. Western Society of Weed Science in cooperation with the Western US Land Grant Universities Cooperative Extension Service and the University of Wyoming, WY.

Wiggins, I.L. and J.H. Thomas. 1962. A flora of the Alaskan Arctic slope. Arctic Institute of North America Special Publication No. 4. University of Toronto Press, Toronto, Ontario, Canada.

Wyoming Natural Diversity Database. 2003. Data compilation for *JnJ Associates* LLC, completed 2003. Unpublished report. Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY.

Wyoming Natural Diversity Database. 2005. Wyoming Natural Diversity Database, Laramie, Wyoming. Available online at: http://uwadmnweb.uwyo.edu/wyndd/ [Accessed November 2005].

Wyoming Weed and Pest Council. Undated. Weed handbook Series 1-55. Wyoming Weed and Pest Council, Douglas, WY.